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WMP-18647
Revision 0

Historical Site Assessment of the Surface Radioactive Contamination of the BC Controlled Area

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Fluor Hanford
P.O. Box 1000
Richland, Washington

Contractor for the U.S. Department of Energy
Richland Operations Office under Contract DE-AC06-96RL13200

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W. J. Millsap

May 2004

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History of the extensive soil contamination area described on the BC Controlled Area, located north of the 200 East Area, is provided.

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The author gratefully recognizes the good work and support contributed by the above personnel.

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TERMS

AEC	U.S. Atomic Energy Commission
ARCHO	Atlantic Richfield Hanford Company
BHI	Bechtel Hanford, Inc. (BHI)
cpm	counts per minute
cps	counts per second
$DCGL_w$	derived concentration guideline level Wilcoxon
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EPA	U.S. Environmental Protection Agency
GM	Geiger-Mueller
ID	identification
MARSSIM	DOE/EH-0624, *Multi-Agency Radiation Survey and Site Investigation Manual*
MDA	minimum detection activity
MPC	maximum permissible concentration
MSCM-II	mobile surface contamination monitor
ORIGEN2	Oak Ridge Isotope GENeration and Depletion
PDF	portable document format
PRTR	plutonium recycle test reactor
REDOX	reduction-oxidation
RESRAD	RESidual RADioactivity (dose model)
RL	U.S. Department of Energy, Richland Operations Office
SAC	system assessment capability
SST	single-shell tank

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	Meters	meters	3.281	feet
yards	0.914	Meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerel	0.027	picocuries

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1.0 INTRODUCTION

The BC Controlled Area,[1] separate from the BC Cribs and Trenches Area,[2] is a waste site that requires assessment and potential remediation. The BC Area,[3] including the Controlled Area and the Cribs and Trenches Area, is shown in Figure 1-1, "BC Area." The total area is about 13.4 mi^2; the immediate area of the cribs and trenches is about 46.7 acres (or about 0.073 mi^2).

Before any necessary remediation can be accomplished, it is first necessary to understand the type, extent, and distribution of any radioactive contamination in the area. This information is developed first by a review of the history of the site (called a historical site assessment) to see what can be learned and to develop a model of the type, extent, and distribution of the radionuclides; and second by surveys that are used to confirm, modify, and extend the model developed by the historical site assessment. This report is the historical site assessment for the BC Area.

The need for a historical site assessment before planning remediation is widely recognized. DOE/EH-0624, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*, is a multi-agency consensus document developed by the U.S. Department of Defense, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the U.S. Nuclear Regulatory Commission. The MARSSIM provides information on planning, conducting, evaluating, and documenting building surface and surface soil final status radiological surveys for demonstrating compliance with dose or risk-based regulations or standards. Chapter 3 of the MARSSIM discusses historical site assessments. In the MARSSIM, the historical site assessment has these functions: (1) identify potential, likely, or known sources of radioactive material and radioactive contamination based on existing or derived information; (2) identify sites that need further action as opposed to those posing no threat to human health; (3) provide an assessment for the likelihood of contamination migration; (4) provide information useful to scoping and characterization surveys; and (5) provide initial classification of the site or survey unit as impacted or non-impacted.

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[1]BC Controlled Area: As used in this report, the term "BC Controlled Area" refers to that part of the BC Area outside the immediate area of the cribs and trenches themselves. See Figure 1-1 for a map showing the boundaries of the area. The reader should be aware that the terms "BC Controlled Area" or "BC Control Area" have had different meanings to different people at different times; when reviewing historical records, it is necessary to pay attention to what the writer meant at the time.

[2]BC Cribs and Trenches Area: As used in this report, the term "BC Cribs and Trenches Area" refers to that part of the BC Area that includes the cribs and trenches and the area immediately surrounding the cribs and trenches. See Figure 1-1 for a map showing the boundaries of the area.

[3]BC Area: As used in this report, the term "BC Area" refers to the area covered by the BC Controlled Area and the BC Cribs and Trenches Area.

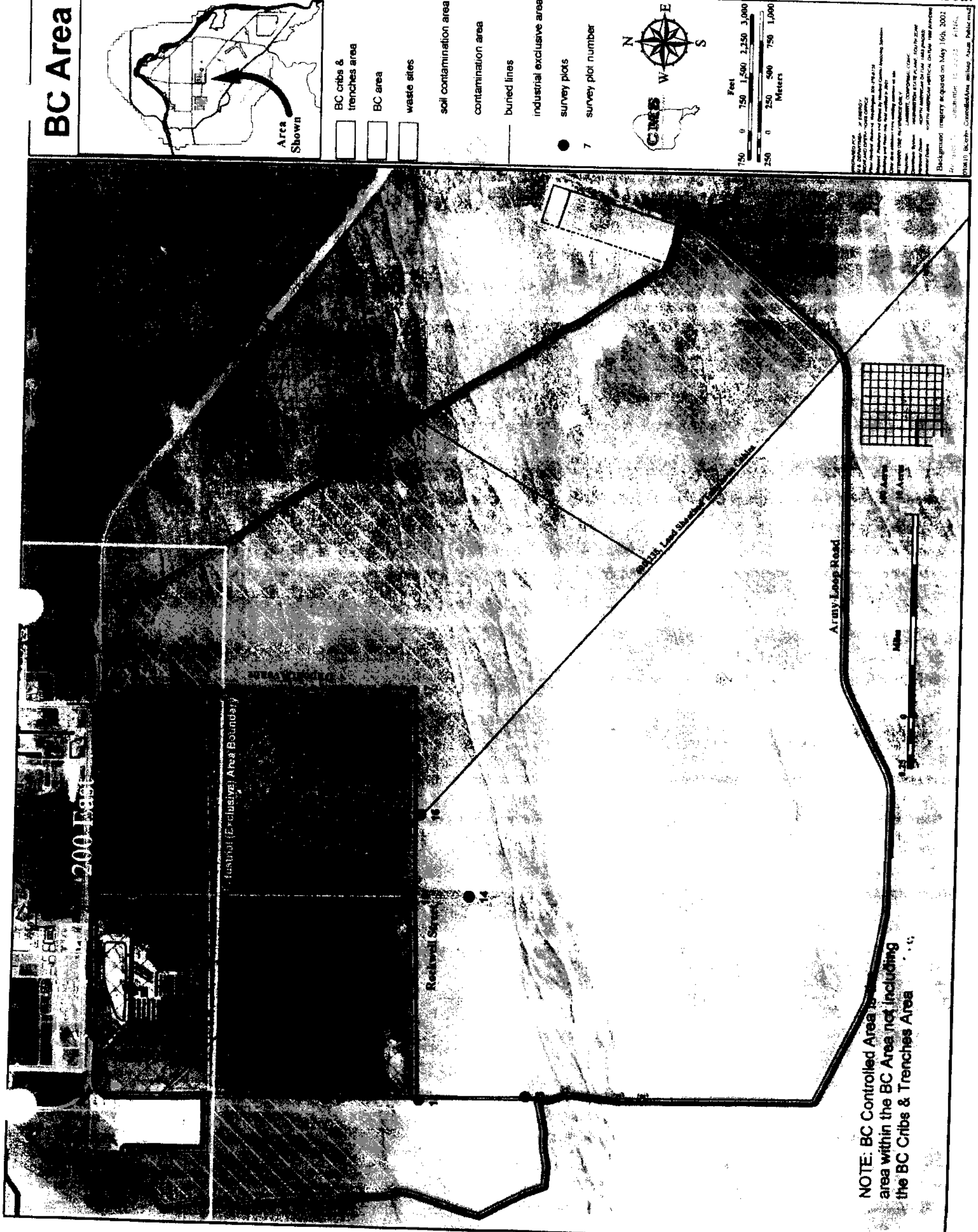

Figure 1-1. BC Area.

This assessment has three main parts: a chronological narrative, a review of the information found that is pertinent to the conceptual model, and the descriptions of the conceptual models themselves. A chronological review is needed to discover the radiological information that is available and to put the technical information into context, because technical information often is recorded with little or no explanation of the overall context of the information. Once the information is gathered, it then is necessary to collect and review that information that would or might be useful in establishing a conceptual model of the contamination on the site. Finally, it is necessary to clearly describe the conceptual model that will be used as the bases for future surveys.

An incidental and secondary use of this report is to record, briefly and sometimes only by reference, peripherally related information that might be of some use in the future of the project; this information primarily is in the chronological narrative (Chapter 2.0) and in Appendices A, B, and C.

Appendix A contains notes from personal interviews; Appendix B identifies historical photographs of the BC Area; and Appendix C provides a record of measurements of biotic contamination found within the BC Area.

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2.0 CHRONOLOGICAL NARRATIVE

In reviewing the record concerning the BC Area, it was noticed that a descriptive narrative could be divided into eight different parts, according to the natural divisions within the history of the area. The discussion in this section is divided into these eight parts and proceeds chronologically from the beginning of the project to the present.

2.1 ORIGIN OF THE WASTE IN THE BC CRIBS AND TRENCHES

The waste in the BC Cribs and Trenches came from two general sources: the uranium recovery project and 300 Area wastes. Most of the waste came from the uranium recovery project. The 300 Area wastes were from the plutonium recycle test reactor (PRTR) and the laboratories.

2.1.1 Uranium Recovery Waste

WHC-MR-0227, *Tank Wastes Discharged Directly to the Soil at the Hanford Site*, gives a good account of the origins on uranium recovery waste and it is given below (figures and tables not reproduced):

> "U Plant was one of the three original fuels-separation facilities, along with B Plant and T Plant, but was never used for that purpose. Later it was converted to recover the uranium from the stored metal waste generated from the fuel reprocessed in B Plant and T Plant. Figure 3 depicts the process and waste stream flow for the uranium recovery process. From 1952 to late 1957, the metal waste was sluiced from the SSTs (single shell tanks) and pumped to U Plant to recover the uranium. The U Plant used the tributyl-phosphate-solvent extraction process to recover uranium. Initially, the resultant uranium recovery waste was returned to SSTs for storage.
>
> While the tributyl-phosphate process efficiently recovered uranium from the sluiced, acidified metal waste, the process generated almost 2 liters of waste for every liter of metal waste processed. The 242-B and 242-T tank farm evaporators had already been put in operation to concentrate and, therefore, reduce the volume of waste stored in the SSTs. Even with this, the tank space was not sufficient to support the uranium recovery mission and to continue fuel-reprocessing operations. The ferrocyanide scavenging process was developed to reduce the volume of wastes that had to be stored in SSTs.
>
> The objective of the ferrocyanide scavenging process was to precipitate the soluble long-lived cesium-137 from the uranium recovery waste supernatant so it could be discharged to the ground. The metal waste contained approximately 90 percent of the long-lived fission products from the fuel reprocessing. It was important, in dealing with all waste streams, to maintain the long-lived fission products in storage. The other principal long-lived fission product, strontium-90, was already essentially insoluble in the neutralized uranium recovery waste and precipitated without adding scavenging chemicals. During the

latter years of the scavenging process, chemicals (calcium nitrate or strontium nitrate) were added to enhance the precipitation of the strontium-90.

The ferrocyanide scavenging process was tested in U Plant in October 1953, when ferrocyanide and nickel were added to the uranium recovery waste. The treated test waste was pumped (approximately 1,893,000 liters [500,000 gallons]) to an SST for settling. Because of poor pH control during the first half of the test, only half of the resultant scavenged waste supernatant was discharged to the 216-T-18 crib. The remainder remained stored in the SST.

Full-scale scavenging of the uranium recovery waste began in late September 1954. By this time, about 80.3 million liters (21.2 million gallons) of unscavenged uranium recovery waste were stored in the tank farms in both 200 East and 200 West Areas. From 1954 to June 1957, the newly generated uranium recovery waste was scavenged in U Plant and transferred to 200 East Area for settling in SSTs. Then it was discharged to the ground. The scavenged supernatant was sampled and analyzed to ensure it was within allowable limits (at the time) before it was discharged to the ground.

Beginning in May 1955, wastes that were stored in 200 East Area from the earlier uranium recovery processing were also scavenged and discharged to the ground. The wastes were routed to the CR vault in the 200 East Area tank farm where the wastes were scavenged. The waste then was routed back to SSTs for settling, and the supernatant subsequently was pumped to the ground. This was referred to as "in-tank farm" scavenging. The scavenging in the CR vault ended in December 1957. The last of these wastes were discharged to the ground in January 1958. The in-tank farm scavenged supernatant also was sampled and analyzed before it was discharged.

Of the total 154,990,000 liters (40,946,000 gallons) of scavenged uranium recovery waste discharged to the ground, approximately 44,290,000 liters (11,700,000 gallons) resulted from the in-tank farm scavenging of the waste stored in 200 East Area tanks. There also were plans to scavenge and discharge the unscavenged uranium recovery waste that was stored in the 200 West Area. Preparations were made, but the waste was never scavenged and it remained stored in the tanks.

The original plan called for discharging all of the scavenged supernatant into cribs. However, in 1956, it was found that cobalt-60 in the supernatant would go to the groundwater and exceed allowable U.S. Atomic Energy Commission (AEC) limits. Cesium-137 and eventually technetium-99 also have been detected in the groundwater as a result of these operations. It was decided then to dispose of the high cobalt-60 waste to the ground using specific retention trenches to preclude the cobalt-60 and other radionuclides from reaching the groundwater. Soil conditions were measured and soil volumes calculated to determine the appropriate volume of liquid to be discharged. For further information and concerns on the use of specific retention trenches, see HW-54599, *A History and Discussion of Specific Retention Disposal of Radioactive Liquid Wastes in the 200 Areas.*

In 1954 and 1955, the scavenged uranium recovery waste supernatant was discharged initially to the BY cribs and to one of the BX trenches in the 200 East Area. From 1956 to early 1958, the supernatant was discharged to the BC Cribs and specific retention trenches located south of the 200 East Area. Table 4 summarizes the volume and total curies discharged to the ground. Not reflected in the total curies is the 1,000,000 plus curies of short-lived ruthenium-106 discharged to the cribs and trenches, which has since decayed to insignificant levels. The Hanford Site workers took great care during the disposal operation to minimize exposure to operating personnel from the radiation given off from the ruthenium."

As mentioned above in the discussion regarding WHC-MR-0227, the discovery of Co-60 in groundwater resulted in the use of specific retention trenches, rather than cribs, for this waste. An investigation concluded that the Co-60 had become complexed at some point in the processing, and, as a result, it was not impeded by the usual soil adsorption mechanisms. This prevented the Co-60 from meeting the "cribbable" limit, and, after June 1956, almost all scavenged waste was disposed of in specific retention trenches. The Co-60 problem is discussed more fully in HW-42612, *Cobalt-60 in Ground Water and Separations Plant Waste Streams* and HW-48862, *Disposal of High Cobalt-60 Scavenged Wastes*. The possibility of complexed radionuclides reaching the groundwater was recognized as early as 1953; see HW-28121, *Release of Radioactive Wastes to Ground.*

As implied by WHC-MR-0227, the basic idea of specific retention seems to have been questioned from the start. In 1958, HW-54599 discussed its use at the Hanford Site. HW-54599 concluded that the value for specific retention capacity in use at that time, 10 percent, was too high and should be lowered to 6 percent. It is worth noting that in 1957 a groundwater mound of about 2 ft was found to underlie the BC Cribs and Trenches Area. It was concluded that if the mound was caused by the 1 million gal per month of scavenged wastes discharging to the trenches, the specific retention of the soil column was less than believed at that time.

2.1.2 300 Area Waste

During the early to mid-1960s, wastes from the PRTR and other laboratory operations in the 300 Area were disposed of in four trenches in the BC Area: 216-B-53A, -53B, -54, and -58. This waste generally is described as low-salt, neutral, and basic waste. Trench 216-B-53A received a relatively large amount of plutonium, 100 g, and uranium, 23 kg, because it received waste from the reactor accident at the PRTR. The total volume was about 2 x 10^6 L (about 522,000 gal) (RHO-CD-673, *Handbook-200 Area Waste Sites*).

2.2 CONSTRUCTION AND USE OF THE BC CRIBS AND TRENCHES

The BC Cribs were in use when the problem with complexed Co-60 was discovered. To avoid the use of cribs, the specific retention trenches were employed as an emergency measure. HW-43101, *TBP Scavenged Waste Trench Disposal Scope Study*, discusses the need and rationale for the trenches, as well as some potential problems with them. These trenches were proposed for use on the basis of a 10 percent volume retention, and HW-43101 noted that "The 10 percent volume retention is higher than theoretical calculations would indicate; however, the extensive lateral spread which generally occurs in the 200 area plateau soils and the radioisotope adsorption were sufficient at the previous sites to attain the predicted retention." HW-43101 also noted that "Uniform distribution of the liquid over the trench bottoms, important if the risk of local penetration to the groundwater is to be minimized, was difficult to achieve." HW-43101 concluded that "The inability to estimate accurately the retention capacity at a new site and the risk of local penetration because of channeling places the open-trenching disposal technique in the emergency use category for the waste being considered."

HW-53225, *Chemical Effluents Technology Waste Disposal Investigations: April, May, June 1957*, reported an early indication that the specific retention calculations might have been in error:

> "Leveling and taping of the wells in the BC crib and trench area show that a small but definite mound with a maximum known elevation of 2 ft underlies the area. If this is caused by the 1 million gallons per month of scavenged waste discharging to the trenches, it indicates that the specific retention of the soil column is less than presently believed."

This emergency use of trenches continued later when Trench 216-B-53A was used to receive part of the contaminated cooling water from the PRTR accident of September 29, 1965. It is worth noting that the waste put into these open trenches was sufficiently radioactive to cause low-energy sky shine to expose the film badges of the day; see HW-46523, *Sky Shine Problems at 200 East Trenches*.

A general explanation of radioactive liquid waste disposal practices by the separations plants is given in HW-45058, *Review of Radioactive Liquid Waste Disposal Practices for Hanford Separations Plants*.

A photograph showing the original area of the BC Cribs and Trenches is given in Figure 2-1. See Figure 2-2 for a map showing the layout of the cribs and trenches.

2.2.1 Cribs 216-B-14 to -19

The BC Cribs were constructed first, about 1955. The six cribs were in service for 2 years from January 1956 until December 1957, and they received waste from the U Plant by a buried pipeline. Each crib is a 10- by 10- by 3-ft high structure consisting of a steel form on top of an array of on-end concrete blocks resting on wood planks. The crib structure, which was fed by a 14-in. diameter inlet pipe, sits on a 5-ft thick layer of 3-in. gravel. The gravel and crib are within an excavation approximately 12 ft deep that measured 40 by 40 ft square at the bottom. Surrounding the crib was another layer of 1/4- to 3/4-in. gravel approximately 2 ft thick. Once each crib had received its allowable volume, it was isolated from the pipeline (RHO-CD-673, Sections on 216-B-14, -15, -16, -17, -18, and -19). The cribs under construction are shown in Figure 2-3; they are shown near completion in 1955 in Figure 2-4. The volumes and total activities received by these cribs are summarized in Section 3.1.1.

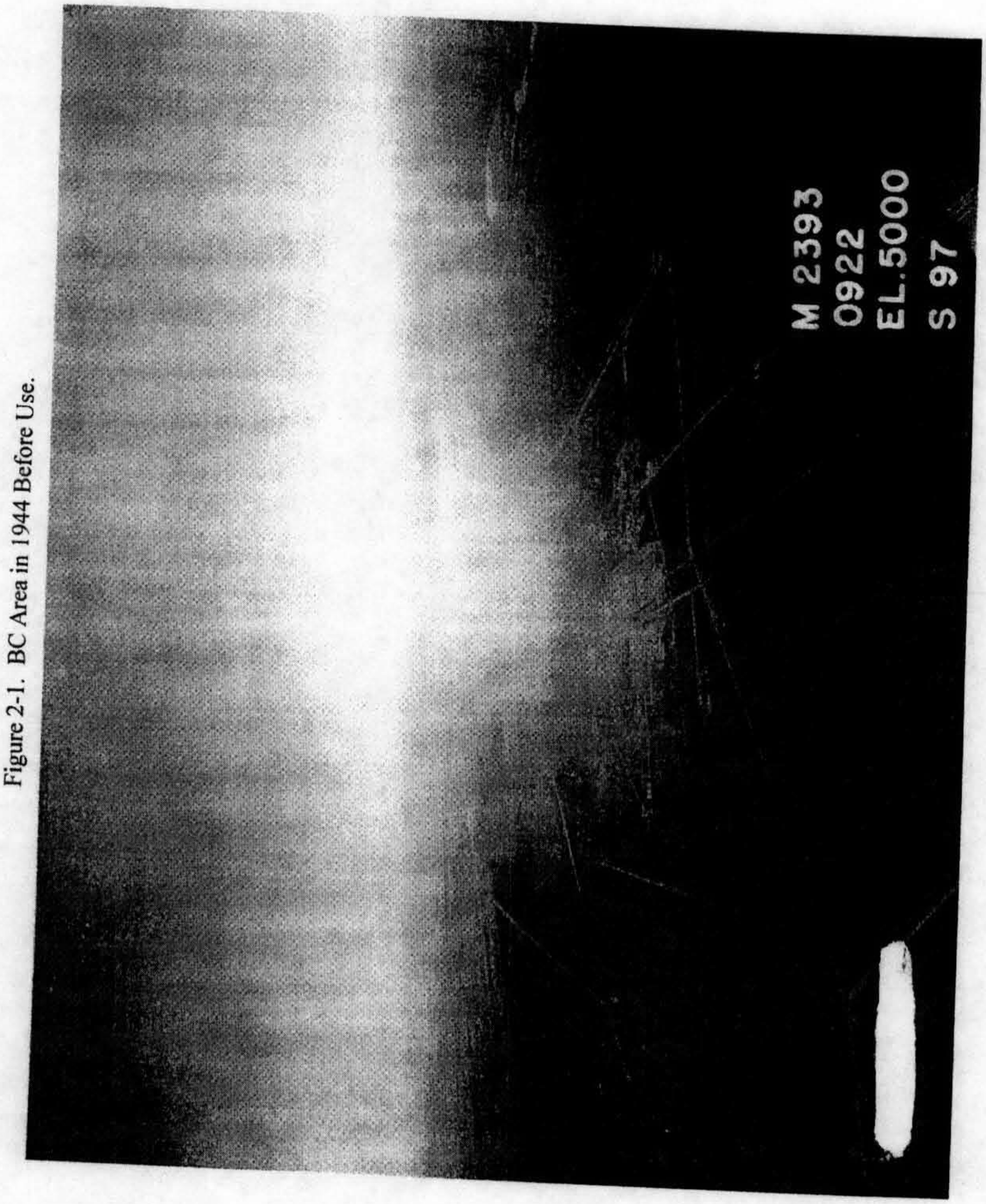


Figure 2-1. BC Area in 1944 Before Use.

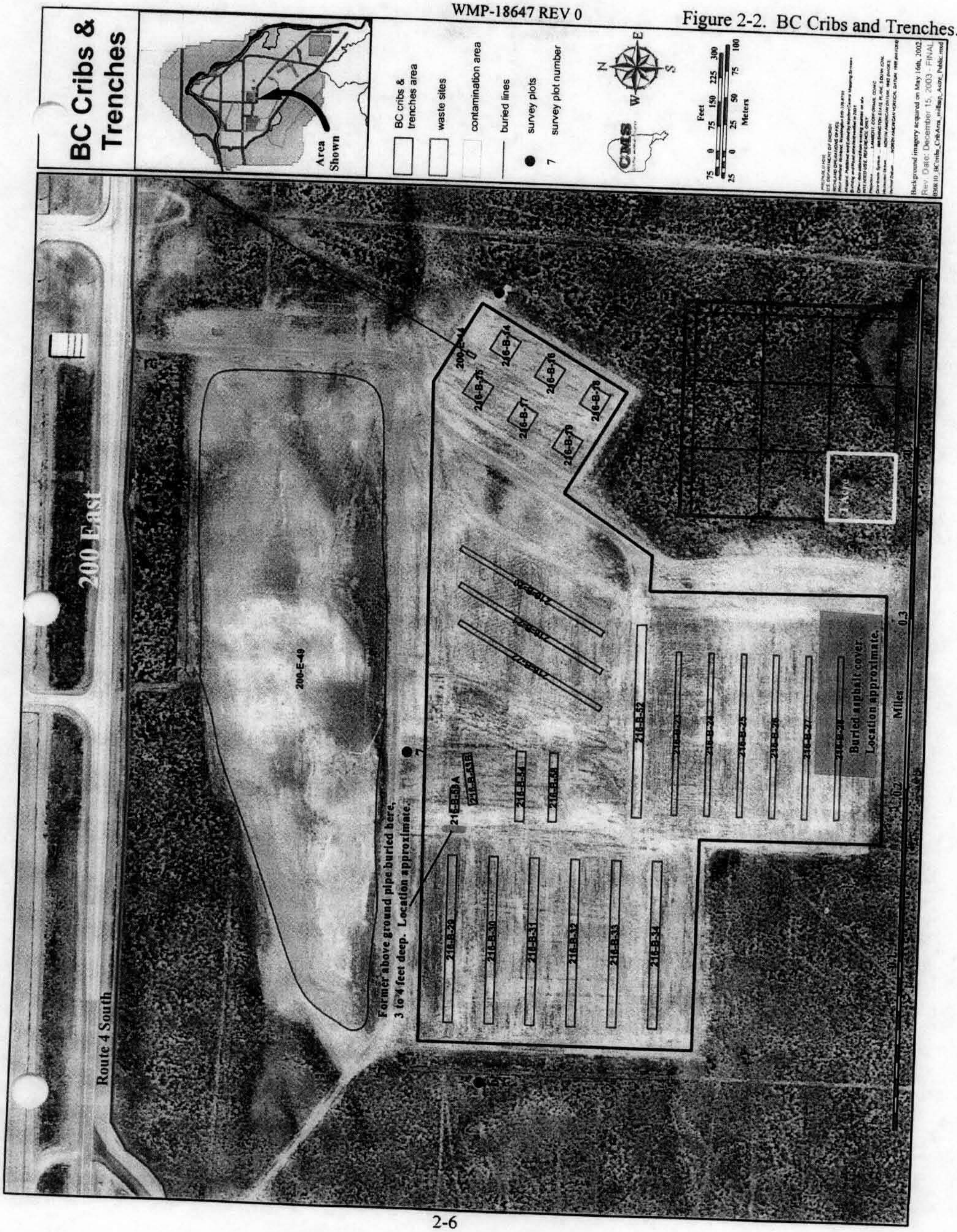


Figure 2-2. BC Cribs and Trenches.

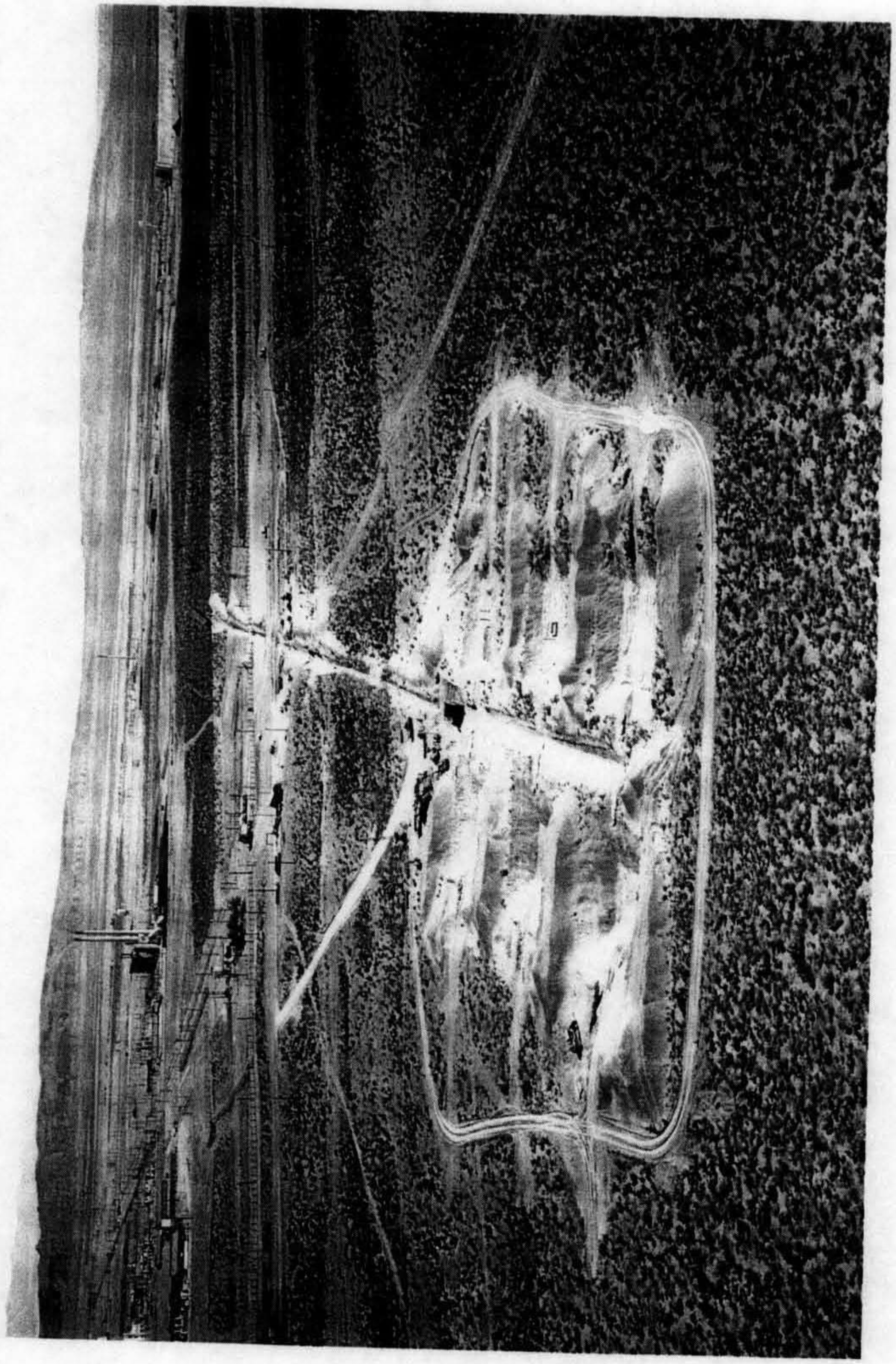


Figure 2-3. BC Cribs Under Construction, June 1955.

Figure 2-4. BC Cribs Near End of Construction, 1955.

A tank-by-tank accounting of the volume of waste sent to the BC Cribs through the third quarter of 1957 is given in HW-54655, *Chemical Effluent Technology Waste Disposal Investigations, July, August, September, 1957.*

ARH-3046, *Engineering Evaluation, Waste Disposal Cribs – 200 Areas*, in an engineering evaluation of the 200 Area cribs, concluded that these cribs are among those most likely to collapse (ARH-3046, Appendix B) and that all wooden cribs ultimately would collapse. In fact, Crib 216-B-18 collapsed in February 1974 leaving a hole 4 ft in diameter and 3.5 ft deep (ARH-3046); a photograph is shown in ARH-3046. No radioactivity was released, but this incident and the conclusions in ARH-3046 about these cribs point to the possibility of further failure.

2.2.2 Trenches 216-B-20 to -22

These trenches were the first of the BC Trenches to receive scavenged waste from the uranium recovery effort. They were in service during August, September, and October 1956 and were considered an emergency measure in order to keep the uranium recovery process going. According to HW-49465, *Chemical Effluent Technology Waste Disposal Investigations, July, August, September, 1956*:

> "Several of the trenches have already been made available and are now receiving waste. Delivery to the first trenches began on July 28, 1956, and through September 1956, the trenches have received 2.5 million gallons of high cobalt-60 scavenged supernate."

The trenches are 500 ft long and 10 ft wide at the bottom. They were to be divided into eight sections by low earth dikes, and one section was to have a plastic cover on a rigid wooden frame (this was to be reused in each section). The trenches were supplied by over-ground piping from an existing stub on the BC Crib supply line just ahead of the siphon tank (see HW-43101). Despite the intended design, the photograph of Trenches 216-B-23 through -28 shows Trenches 216-B-26, -27, and -28 divided into three, rather than eight, sections.

A summary of the volume and activities received by these trenches is given in Section 3.1.2.

For photographs of open trenches, see Figures 2-5 and 2-6.

2.2.3 Trenches 216-B-23 to -28 and -52

These trenches were the second set dug to receive scavenged waste and were in service from October 1956 until January 1958. They received almost 10 million gal of waste.

A summary of the volume and activities received by these trenches is given in Section 3.1.3.

Figure 2-5. Trenches Under Construction in 1956.

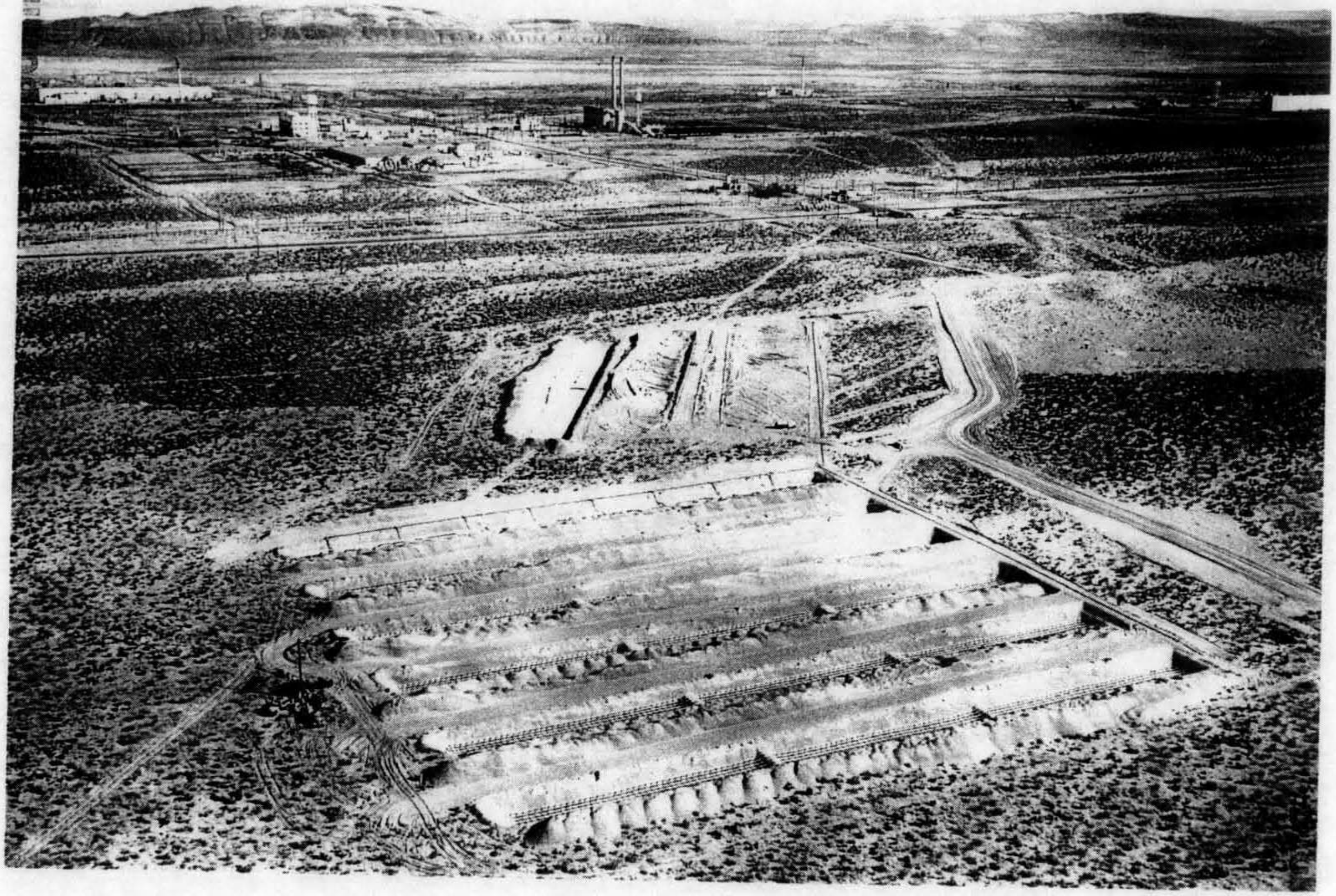
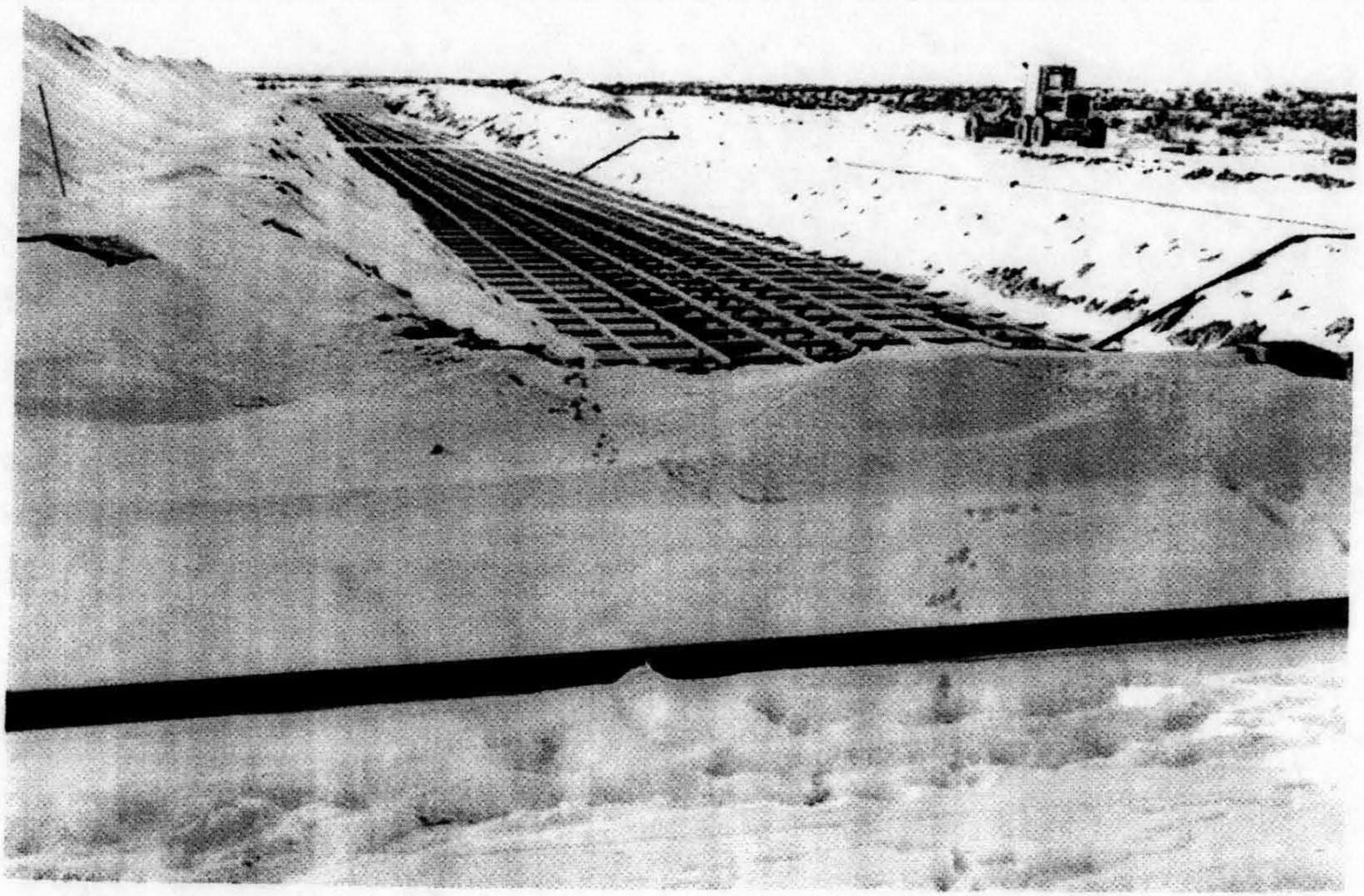


Figure 2-6. Trench Showing Piping and Wooden Lattice, 1957.



2.2.4 Trenches 216-B-29 to -34

This was the last set of trenches dug to receive scavenged waste. They were in service from June 1957 until October 1957. They received about 7.5 million gal of waste.

A summary of the volume and activities received by these trenches is given in Section 3.1.4.

2.2.5 Trenches 216-B-53A, -53B, -54, and -58

These trenches received waste from 300 Area laboratory operations and the PRTR accident on September 29, 1965.

The waste in Trench 216-B-53A, attributed to the PRTR in RHO-CD-673 (as noted above), is the contaminated cooling water resulting from an accident at the PRTR on September 29, 1965 (*WIDS General Summary Report on Site Code 216-B-63A*). A discussion of this accident is given in PNL-5003, *Plutonium Recycle Test Reactor (PRTR) Accident*. No further information on the origins of the waste in the other trenches has been found. These trenches received waste from November 1962 until June 1967.

Thus, the cribs and trenches received scavenged waste from January 1956 until about January 1958, a period of only 2 years. Reactor accident and laboratory wastes from the 300 Area were received in trenches at various times from November 1962 until June 1967, a period of about 4 1/2 years.

A summary of the volume and activities received by these trenches is given in Section 3.1.5.

2.2.6 Aboveground Piping Burial Trench

RHO-CD-673, Vol. III, 216-B-20, records that "the above ground transfer piping to the trenches was removed and each length of pipe was buried in a shallow trench, 3 to 4 ft deep, between Trenches 216-B-29 and 216-B-53A. The pipe burial lays centerline north and south at approximate coordinates, N-36000, W-54800." Al W. Conklin (see Appendix A) also reported his recollection that the pipe is buried in this location. The location of the buried pipe is shown in Figure 2-2. This pipe also showed up as a distinct hot spot on the aerial gamma surveys of 1973 (EGG-1183-1661, *An Aerial Radiological Survey of the U.S. Energy Research and Development Administration's Hanford Reservation [Survey Period: 1973-1974]* and 1978 (EGG-1183-1828, *An Aerial Survey of the U.S. Department of Energy's Hanford Site, Richland, Washington [Date of Survey: May-June 1978]*). The results of the 1973 aerial survey are shown in Figure 2-7, and the results of the 1978 aerial survey are shown in Figure 2-8.

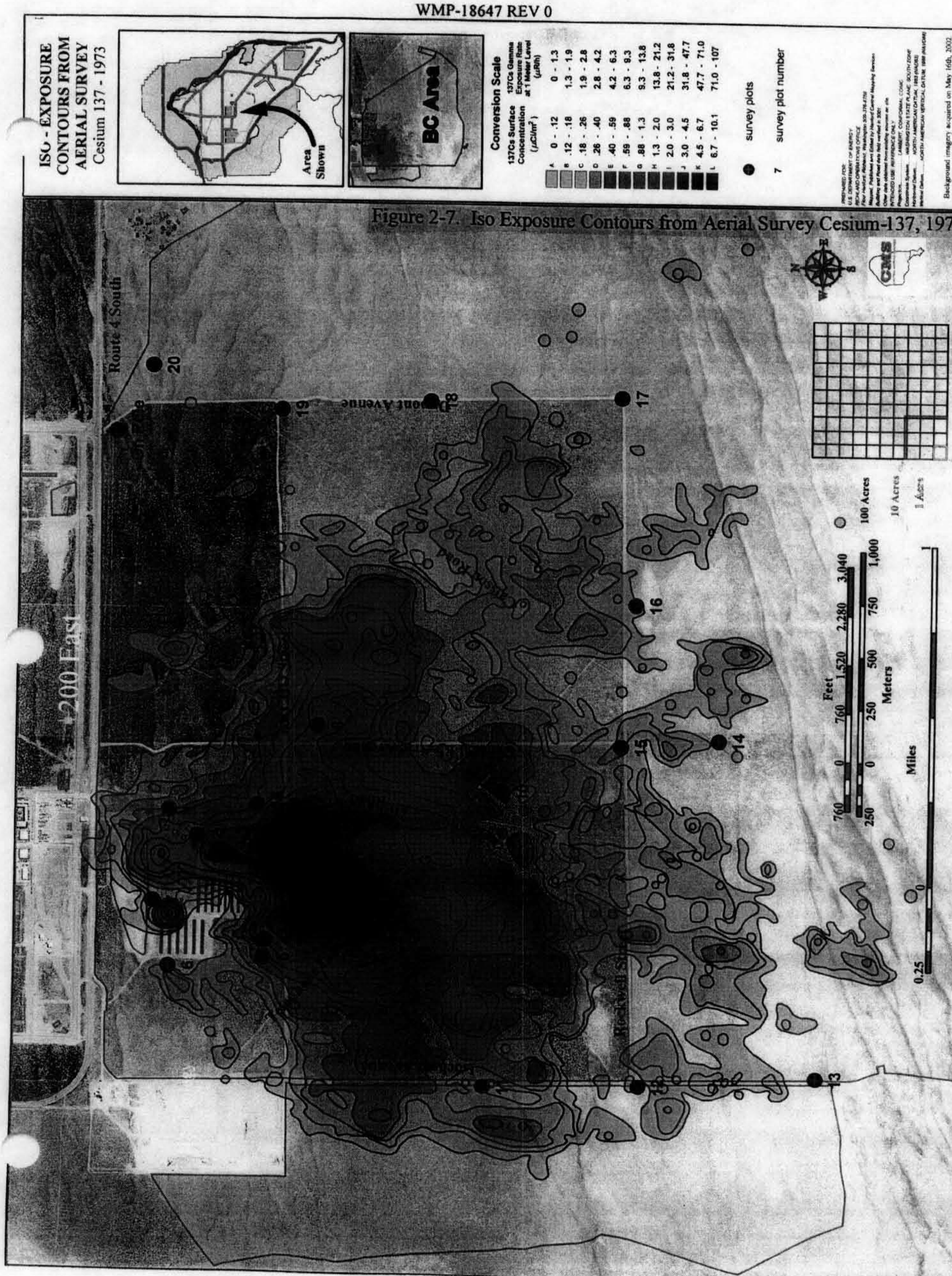


Figure 2-7. Iso Exposure Contours from Aerial Survey Cesium-137, 1973.

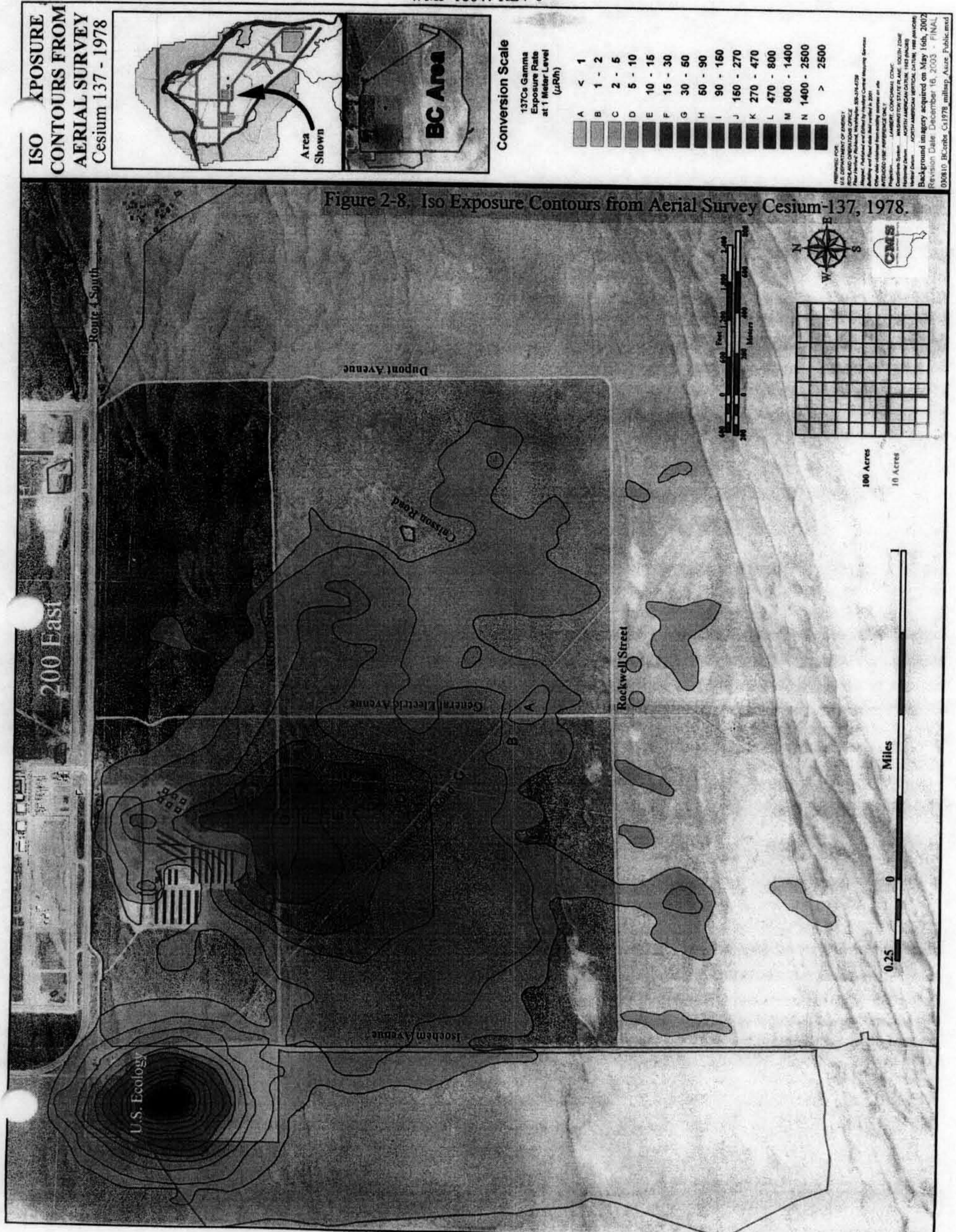


Figure 2-8. Iso Exposure Contours from Aerial Survey Cesium-137, 1978.

2.3 INITIAL BIOLOGICAL CONTAMINATION SPREAD AND INITIAL CONTROL EFFORTS

The earliest record found of animal contamination in the BC Cribs area is Survey No. DS 01266, "Followup Survey of Contamination Reported in the East Area," dated May 7, 1958; it records the maximum dose rate on some radioactive rabbit droppings as 2,000 mrad/h. The trenches still were being used at this time, because the same survey reports that the dose rate on the overground line (4 in.) was 250 mR/h at what appears to be a distance of 2 m from the pipe. Survey No. DS 01856, "Survey Drilling Rig," September 8, 1958, reported contamination levels of 40,000 counts per minute (cpm) over most of the frame of a drill rig working in the BC Crib area. Survey No. DS 01900, "Survey of Hot Vegetation in the BC Crib Area," September 17, 1958, reported plants in the bottom of a ditch reading 5,000 mrad/h; bags of vegetation reading 7,000 mrad/h; and rabbit droppings reading 40,000 cpm. Thus, in the summer of 1958 at the latest, heavy plant and animal contamination was known to be present in the BC Cribs and Trenches Area, and it should have been clear that the contamination would have been spread by the animals.

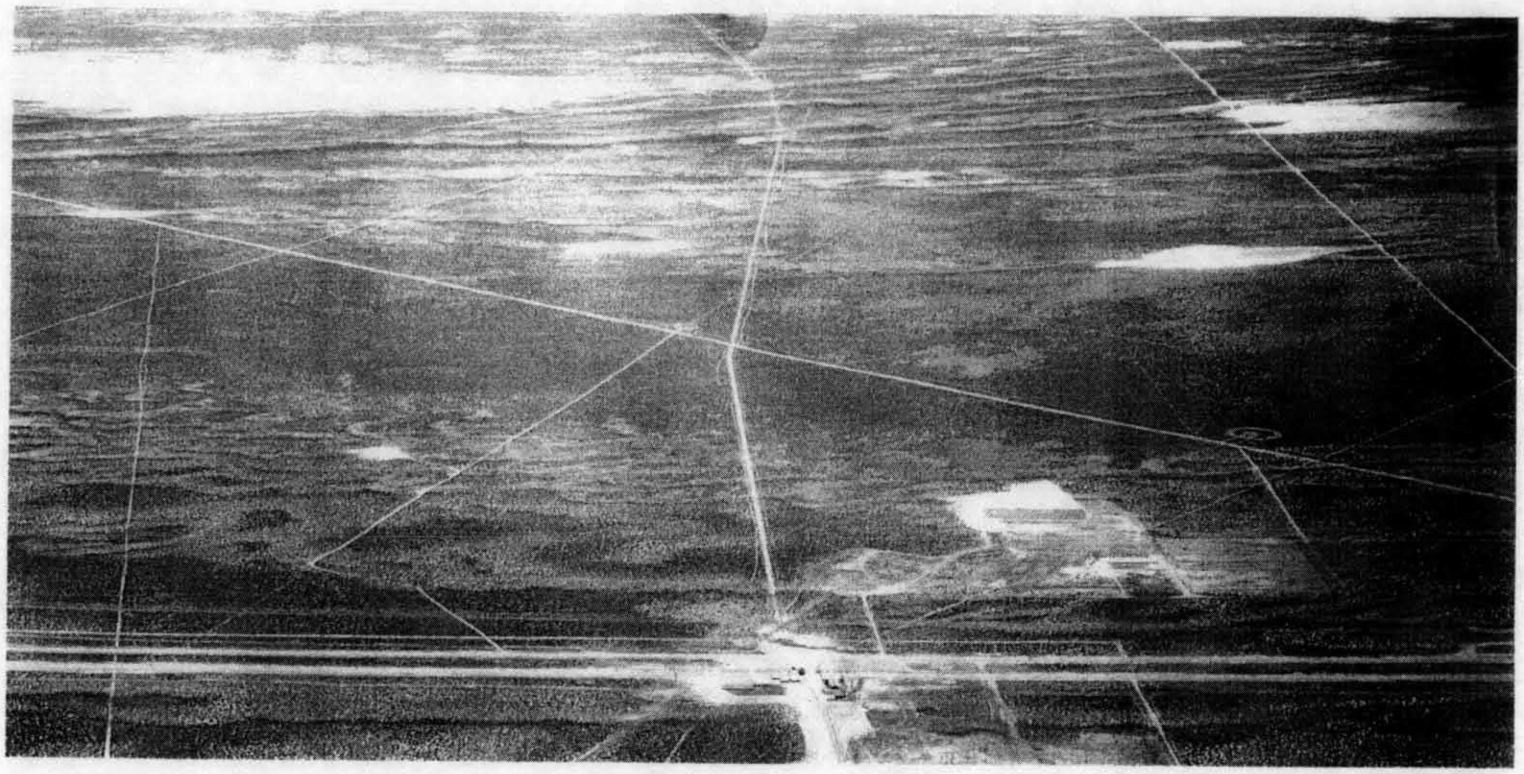
Sometime during the period of 1958 until 1960, most likely 1958 but estimates vary, animal intrusion into the trenches was noted to be taking place. The main burrows were reported to be in Trench 216-B-28, and this makes sense, because Trench 216-B-28 is the greatest distance from human activity and borders on the dense sagebrush areas to the south. It was reported that the contamination was due to a single badger hole, but this is unlikely, because to release the estimated levels of environmental activity, this badger would have had to excavate over half of a 500-ft trench (RHO-CD-673 reported that Trench 216-B-28 received 110 Ci of Sr-90 and 23 Ci of Cs-137). "Status of BC Crib Surface Contamination Development Work" (Bruns 1974a) issued to provide the status of the BC Cribs surface contamination development work in 1974, estimated the activity on the surface to be 81.5 Ci of Sr-90 and 14.5 Ci of Cs-137. It seems likely that many small animals over a period of 6 to 7 years burrowed into the shallow cover and ate the salt cake. During a review of BC Area historical data in 1987, "BC Cribs Controlled Area Historical Data" (Johnson 1987) noted that burrows from many species have been observed in the area. However it took place, animals, primarily rabbits, used the exposed salt as a "salt lick" and then defecated and urinated over a large area, resulting in the contamination of about 4 mi^2 of sagebrush area to the south, east, and west.

In spite of the extent of the contamination spread, there is no record of action being taken to stop this intrusion for 5 to 7 years, when in 1965 the holes in Trench 216-B-28 were filled in and an asphalt pad was poured onto about two-thirds of the trench. This pad is shown in the photos reproduced in Figures 2-9 and 2-10. An overview of the area at about that time is seen in Figure 2-11. By this time, it is likely that the major environmental contamination presently in the BC Controlled Area had taken place. Four years later, in 1969, about 60,000 yd^3 of sand and gravel were used to cover and stabilize the BC Trenches (ARH-3088, *A Preliminary Safety Analysis of the B-C Cribs Controlled Area*), thus halting most of the remaining spread of contamination from these sources by animals.

Figure 2-9. BC Cribs and Trenches Area Showing Asphalt Pad, September 1965.

Figure 2-10. BC Trenches Showing Asphalt Pad, September 1965.

Figure 2-11. Area Surrounding BC Cribs and Trenches, 1966.



2.4 RESEARCH INTO CLEANUP AND BUILDING FIREBREAKS

After the BC Trenches were covered in 1969, it was clear that there was a potentially hazardous situation with the remaining area of about 4 mi^2 that was contaminated. There were concerns about the further spread of contamination by wind, plants, and animals, and, in particular, the spread of contamination during and after a range fire (see "B-C Crib Unplanned Radioactivity Release Cleanup" [Bruns 1972]).

In 1972, a program was developed to study the contamination and determine the best approach to dealing with the situation (see Bruns [1972]). This program resulted in extensive studies of the distribution of the contamination and the physical and biological forces that could spread the contamination, as well as the potential doses resulting from this contamination. The results of these studies are largely summarized in the appendices of ARH-3088. These efforts are summarized briefly below, and some specific radiological information is reviewed in Section 3.0 of this report.

2.4.1 Distribution of Radioactive Material

During this period, there was an extensive effort to determine the distribution of radioactive material surrounding the BC Cribs and Trenches Area. These included an aerial gamma survey using sodium iodide detectors, an extensive walking survey with Geiger-Mueller detectors carried out by the Battelle-Northwest Laboratories, in-situ measurements of exposure rate, and soil sampling and analysis, including some to show depth distribution of radionuclides, mostly Sr-90 and Cs-137. An overview photograph of the area at this time is given in Figure 2-12.

2.4.1.1 Airborne Gamma Survey

An aerial gamma survey of the BC Area was completed by EG&G, Inc., Las Vegas Area Operations, on May 30 and June 1, 1973, using sodium iodide detectors onboard a helicopter. The results of the survey for the Cs-137 gamma ray are shown on Figure 2-7. This survey shows the general extent of the Cs-137 contamination resulting from the animal intrusion. Note the heavy concentration of activity south of the trenches and just south of ARHCO Street. To put the size of this contaminated area in perspective, Figure 2-13 shows its size relative to the sizes of the 200 East and 200 West Areas. This survey is described in detail in EGG-1183-1661 and ARH-SA-226, *Aerial Gamma Survey by Helicopter to Measure Surficial Contamination.*

2.4.1.2 Jackrabbit Pellet Survey

During June 1972 and May-June 1973, the Battelle-Northwest Laboratories conducted an extensive walking field survey to determine the extent of the distribution of radioactive jackrabbit pellets and other contamination in the area around the BC Cribs and Trenches. In 1972, Battelle-Northwest Laboratories surveyed 2,625 small circular sampling sites along 30 transects radiating out 2.4 to 3.2 km from the southern part of the BC Cribs and Trenches. In May-June, 1973, 48 additional transects were run: 7 were parallel to lines established in the BC Cribs and Trenches Area in 1972; 18 radiated from an abandoned gun battery site 3.2 km

Figure 2-12. BC Cribs and Trenches Area from the East, 1973.

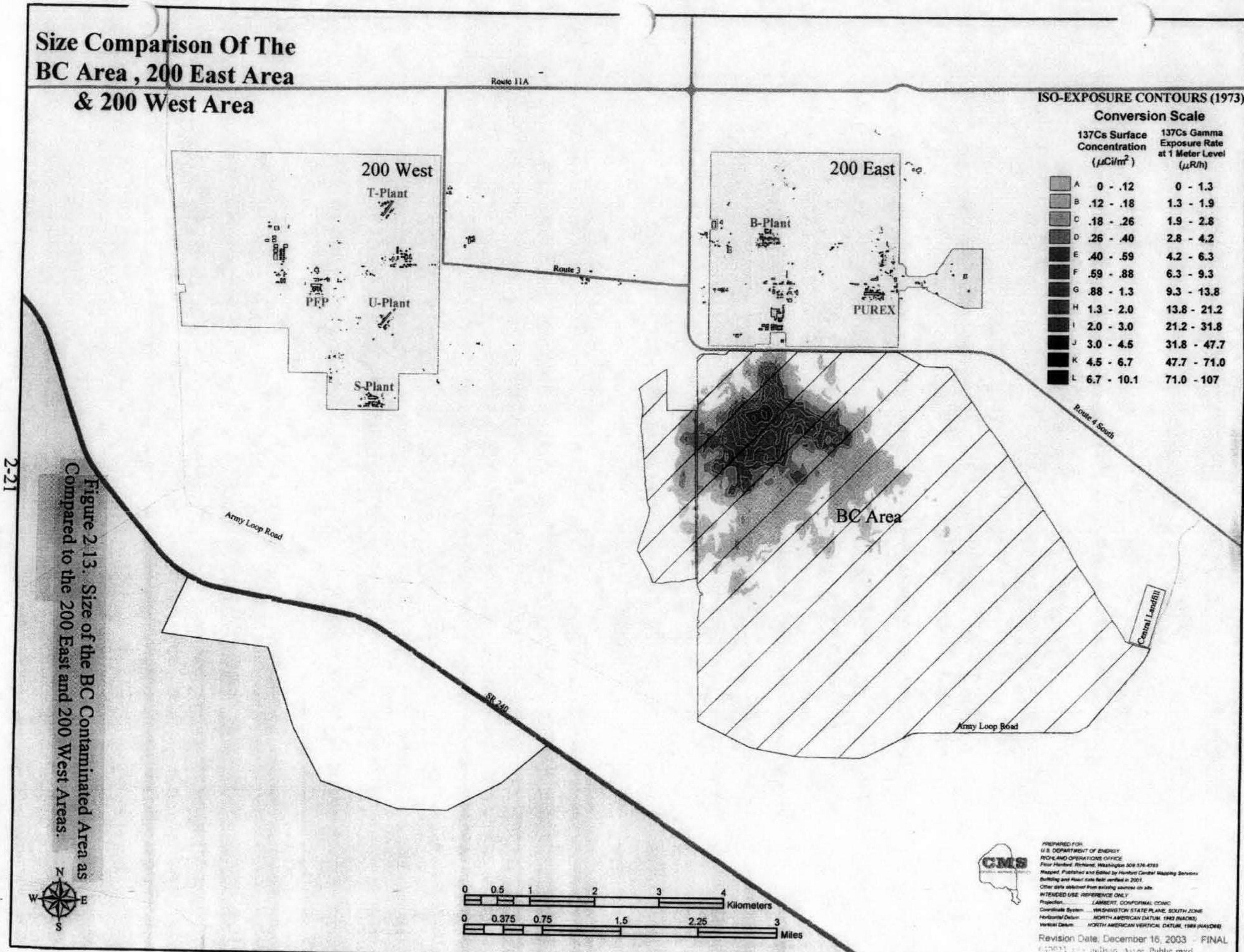


Figure 2.13. Size of the BC Contaminated Area as Compared to the 200 East and 200 West Areas.

east of the cribs; and 23 were run from power lines 5 km south to southwest of the BC Cribs and Trenches Area along Army Loop Road back toward the source of contamination. The results of this survey are shown on Figures 2-14 and 2-15. This survey, which was done with Geiger-Mueller detectors, concluded that the activity generally is confined within the area of the present firebreak roads. Note, however, the activity spread shown by the transect running west below the U.S. Ecology site.

In total, during 1972 and 1974, field crews walked 106.7 km along 28 radii and recorded observations on 6,671 sampling units of approximately 1.4 m^2 each. The area of 1.4 m^2 is the area a person could survey while stooped at one location. Section 3.2.1 describes this survey in more detail.

These surveys are described in detail in BNWL-1794, *Distribution of Radioactive Jackrabbit Pellets in the Vicinity of the B-C Cribs, 200 East Area, U.S.A.E.C. Hanford Reservation* and "Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation" in *Health Physics*.

2.4.1.3 Soil and In-Situ Measurements

L. E. Bruns oversaw an extensive series of soil and in-situ exposure rate measurements during the period from about 1972 to 1974. Unfortunately, much of these data have not been found and probably never were fully summarized and analyzed. However, "Status of BC Crib Surface Contamination Development Work" (Bruns 1974a) discussed exposure rates, soil concentrations, strontium-to-cesium ratios, soil depth profiles, and an estimate of the total activity dispersed. The total activity was estimated to be 81.5 Ci of Sr-90 and 14.5 Ci of Cs-137 (with a considerable uncertainty). Exposure rates in the area were 100 to 1200 mR/yr with most of the high areas between 300 to 700 mR/yr; the background exposure rate was 60 to 80 mR/yr. The soil depth profiles for strontium and cesium showed deeper penetration than generally found for areas contaminated with fallout. The strontium-to-cesium ratios varied with soil depth, with the ratios getting larger as the depth gets greater. The highest value for Sr-90 found was 70 nCi/cm^3 of soil; the highest value for Cs-137 was 25 nCi/cm^3 of soil. Other nuclides found in some abundance were Pu-239/240, Eu-155, Co-60, and Am-241.

BNWL-B-337, *Distribution and Potential Release of Surface Contamination, Cs-137 in Zone 1, B-C Control Area—Interim Report*, characterized the Cs-137 activity on the surface (to a depth of 1 cm) of ten 1 m^2 plots chosen randomly in the most contaminated area south of the actual cribs and trenches. BNWL-B-337 measurements showed that 90 percent of the activity is in the soil and most of the remaining 10 percent is in animal droppings. Very little was found to be in organic debris and vegetation. The average total Cs-137 contamination level to a depth of 1 cm was found to be about 13.3 μCi/m^2.

These results are discussed in detail in "Status of BC Crib Surface Contamination Development Work" (Bruns 1974a), "Dose Rate Studies in the BC-Cribs Controlled Area – May and June 1973" (Bruns 1974b), and BNWL-B-337.

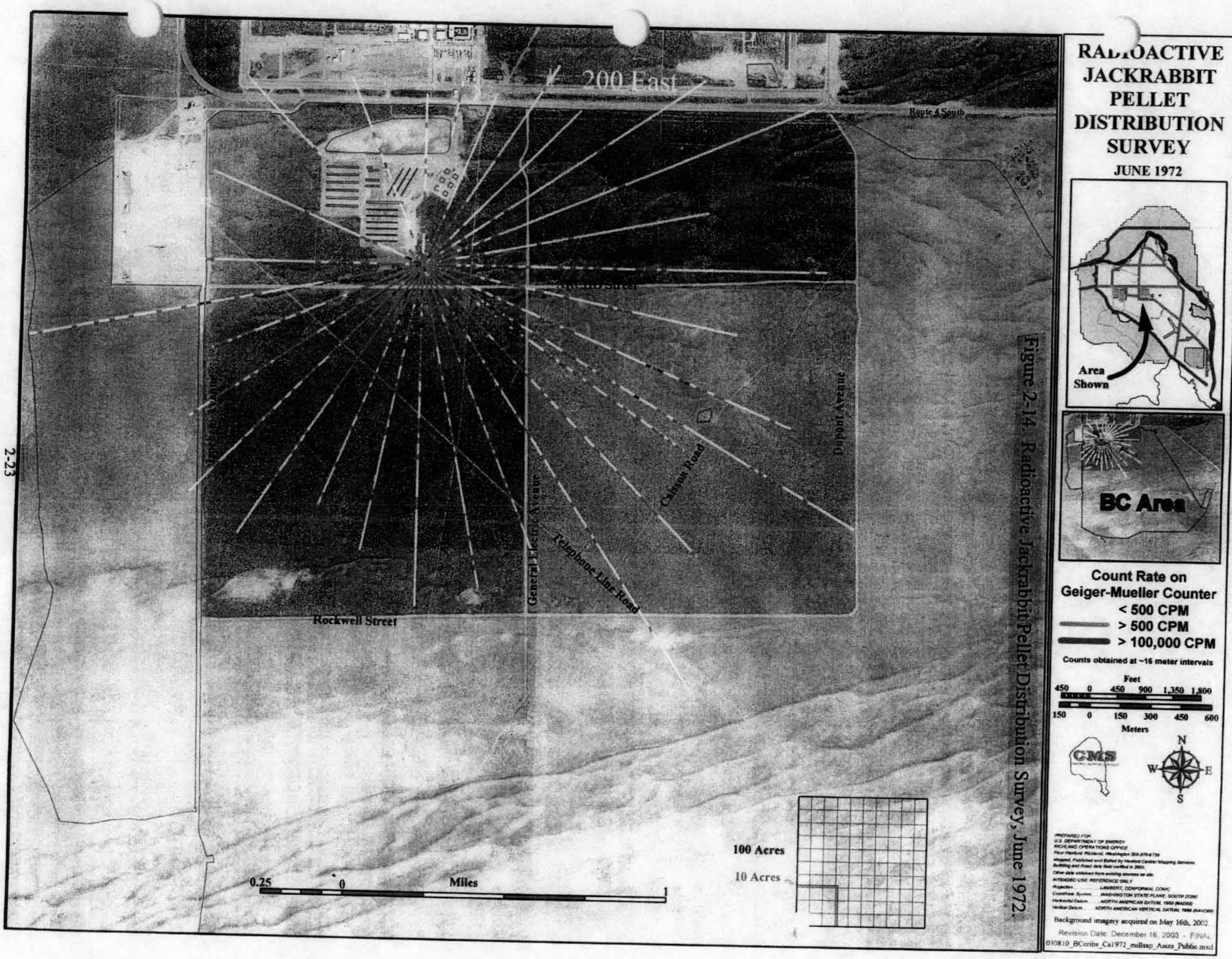


Figure 2-14. Radioactive Jackrabbit Pellet Distribution Survey, June 1972.

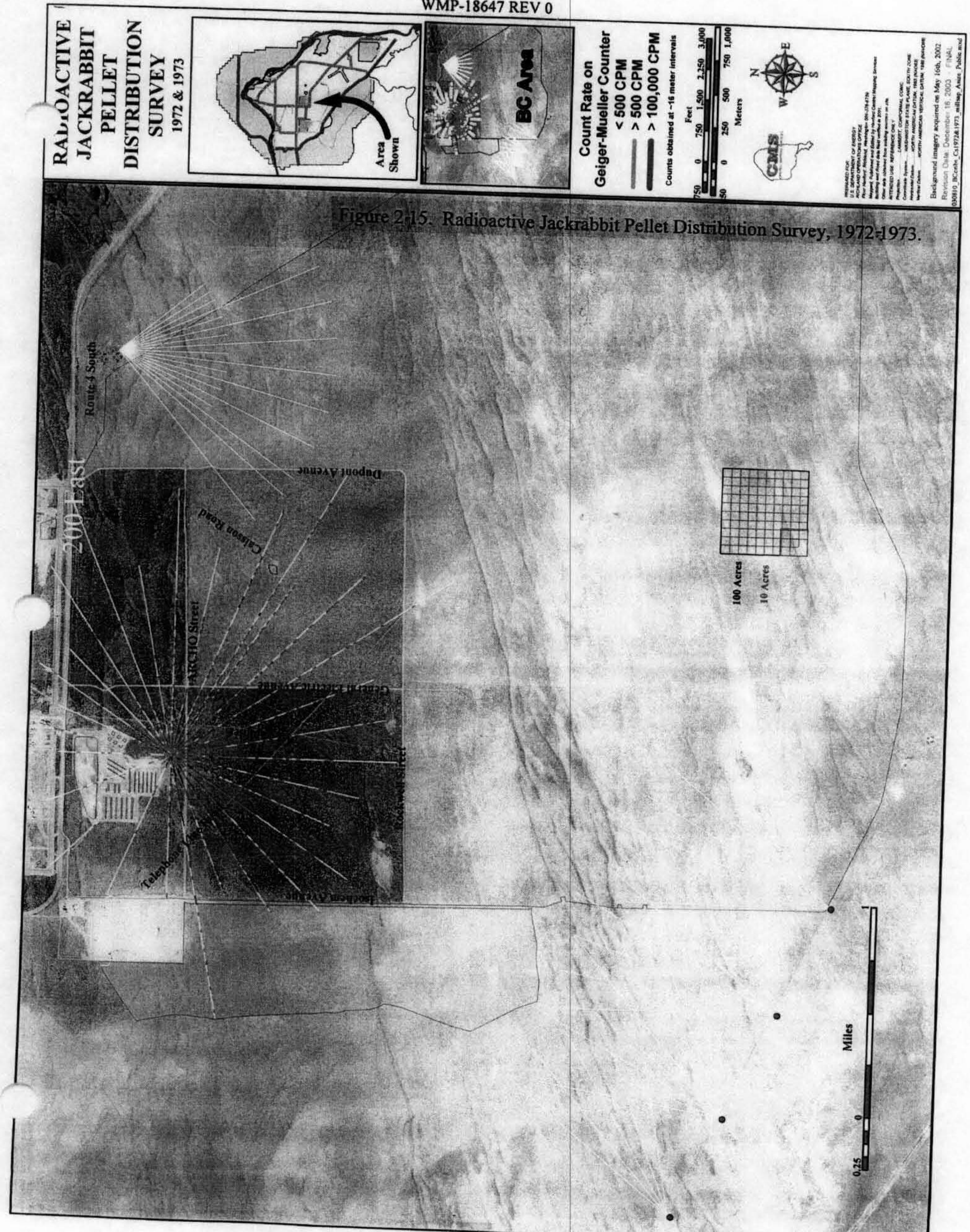


Figure 2-15. Radioactive Jackrabbit Pellet Distribution Survey, 1972-1973.

2.4.1.4 Airborne Spread

Particle resuspension in the area of the BC Cribs and Trenches was researched by G. A. Sehmel during the period of about 1972 to 1974. To study resuspension, 14 towers with air samplers at 1, 6, and 20 ft heights were erected near the most contaminated part of the area around the BC Cribs and Trenches. Three of the towers were upwind of the heavily contaminated areas and 11 were downwind, on 100-ft spacings. Measurements of airborne concentrations of Cs-137 and Sr-90 were orders of magnitude less than the maximum permissible concentration $(MPC)_{air}$ for continuous exposure. From studies across the Hanford Site, it was concluded that airborne concentrations increase as a function of windspeed to the 1.0 to 1.5 power (as opposed to a power of 3 as previously thought). There has been some speculation that these towers also were used to study the dispersion of intentionally released radioactive tracers; no documented information that even hinted at this was found.

These studies are summarized in "Particle Resuspension at B-C Area" (Sehmel 1974) and BNWL-2081, *Radioactive Particle Resuspension Research Experiments on the Hanford Reservation.*

2.4.1.5 Spread by Animals

"Biological Transport of Radionuclides from the B-C Crib Area" (Rickard 1974) reported that, of the common animals in the area of the B-C cribs and trenches, the coyote, badger, Swainson's hawk, meadowlark, and the migratory grasshopper could leave the reservation. The black-tailed jackrabbit and gopher snake could range out as far as 5 miles. Thus, it is possible for activity to be spread to a considerable distance from the BC Cribs and Trenches Area by animals. Nevertheless, upon consideration, Rickard concluded "Only small amounts of radionuclides can be expected to be transported biologically from the B-C Crib area under existing environmental conditions."

2.4.1.6 Spread by Plants

"Biological Transport of Radionuclides from the B-C Crib Area" (Rickard 1974) reported that only two species of plants are likely to be blown from the area of the BC Cribs and Trenches: tumbleweed and tumble mustard. Both of these plants can extract strontium and cesium from their root areas. Rickard reported that "With strong winds, it is possible for tumbling plants to be transported off the reservation." Nevertheless, upon consideration, Rickard concluded "Only small amounts of radionuclides can be expected to be transported biologically from the B-C Crib area under existing environmental conditions." Thus, over the years, radioactive plant fragments could be scattered around the area of the BC Cribs and Trenches.

2.4.2 Consideration of Options for Cleanup

During the period from about 1971 until 1974, while research into the contamination and associated risks was being pursued, various cleanup options for the BC area were being considered. "B-C Crib Unplanned Radioactivity Release Cleanup" (Bruns 1972) discussed the cleanup program and some options. The development program included resuspension studies to determine the airborne risks during and after fires, day-to-day risk from deteriorated rabbit pellets, the risk to workers during removal, etc. Vehicle-mounted multi-channel or single-channel gamma analyzers also were considered. The use of commercial vacuums and perhaps other pellet removal techniques were discussed. Furthermore, the memo mentioned the need to study potential contamination spread by plants and animals.

Bruns (1972) discussed cleanup options according to three cleanup categories—A, B, and C—and three zones—1, 2, and 3. The cleanup categories are those contained in ARH-2164, *Preliminary Problem Definition: Decommissioning the Hanford Site*. Category A would be facilities and areas that could be released for public use without restriction. Category B would be facilities and areas to which the public could have casual access but would be restricted to the actions they could take. For example, the purposeful use of heavy equipment would be required to reach contaminated material. All points that are accessible without such an overt act would be made to meet the criteria of Category A. Category C would be those facilities and areas to which public access would be denied because of AEC programmatic activities. See Table 2-1, "Cleanup Categories Discussed by L. E. Bruns in 1972."

Table 2-1. Cleanup Categories Discussed by L. E. Bruns* in 1972.

Category	A	B	C
Ownership	Private	AEC	AEC
Private Access	Free	Free	Limited
Private Use	Free	Limited	Denied
AEC Surveillance	Minimal	Periodic	Continuous

*Bruns, L. E., 1972, "B-C Crib Unplanned Radioactivity Release Cleanup," Letter from Atlantic Richfield Hanford Company, to R. E. Isaacson, Atlantic Richfield Hanford Company, November 9.

AEC = U.S. Atomic Energy Commission.

This study assumed that solid matrices with plutonium less than 100 pCi/g and fission products less than 2 nCi/g could be considered uncontaminated.

Bruns (1972) related that the Cs-137 alone is 2 to 100 times greater than the 2 nCi/g value in most of the rabbit pellets and associated areas, and this does not consider the Sr-90, which is most of the activity. Bruns also related that the goal that was being considered nationally for exposure in and around nuclear facilities was that the non-occupational exposure should not exceed weapons testing fallout, 25 mrad/yr. Bruns further related that because the B-C Cribs were orders of magnitude above this value, the area definitely should be decontaminated.

Bruns (1972) argued that the decontamination category should be Category B. Bruns concluded that the cost of reaching Category A status would be huge and the benefits derived would not be sufficient to warrant such cost. ARH-2164 estimated that the grossly contaminated area around the BC Cribs covered 250 acres and the volume of soil contaminated was 10,890,000 ft^3; it also estimated the scattered contamination covered 3,000 acres and the volume of contaminated soil in this part was 1,000,000 ft^3. Bruns concluded that treating the land as Category C and leaving it like it is was not justified due to the risk of spread by fire, whirlwind, or biota, despite a several million dollar cost of cleaning the area to a Category B status.

Bruns (1972) did not define the three zones, but they probably are the ones given in "216 BC Contamination Removal" (Ufkes 1973). Zone 1 is the area of highest activity, Zone 2 is lower, and Zone 3 is the lowest. In Bruns' words:

> "The task to achieve Category B status is, briefly, removing 6 inches of soil in the Zone 1, 150 acres of heavily contaminated area, and burying it in the East Area rock pit; the stripped land being reseeded and irrigated. Zone 2 and possibly Zone 3, the less contaminated areas, would be vacuum cleaned and the vacuum recovery accumulations buried in the East Area pit. Modifications of this task might be considered, such as (1) manually removing the contamination by employing a large number of people and storing the contamination in drums or a pit, (2) vacuum cleaning all zones, (3) affixing the activity in Zone 1, e.g., covering it with rock and using a herbicide spray to prevent vegetation growth, and vacuuming Zones 2 & 3, and (4) removing the soil from Zone 1 and leaving Zones 2 and 3 as is."

Later, on August 16, 1973 ((Ufkes 1973), the plan apparently had been modified somewhat to include the removal of the top 6 to 9 in. of 600 acres by earth-moving equipment and burying the soil in the rock pit. Grass would be planted on the stripped area and be irrigated. Furthermore, individual pre-marked spots (over what area was not specified) would be vacuumed with a truck-mounted vacuum source and collection bin.

Some additional alternatives are discussed below in the review of ARH-3088. Some of the documents that are referenced in available documents that discuss cleanup options have not been found.

2.4.3 The Firebreak Roads and Maxfield's Preliminary Safety Analysis (ARH-3088)

In the fall of 1973, apparently acting on the understanding that the greatest threat from the contamination in the BC area was the dispersion of the activity by a range fire, Atlantic Richfield Hanford Company (ARCHO) constructed 10 ½ miles of firebreak and gravel roads around the bulk of the contaminated area ("Program for BC-Crib Controlled Area" [Luening c. 1974]). The firebreaks were 50 ft wide, and the 20-ft gravel road was to allow immediate access for fire-fighting equipment. These firebreaks and roads still exist and are in use and are shown on Figures 1-1 and 2-8, as well as other figures in this report.

Subsequent to the construction of the firebreaks, in July 1974, ARH-3088 was published, which summarized the development efforts that had taken place and offered five alternatives, with some analysis, for consideration. The analysis concluded that "The greatest concern is the potential for surface contamination in the B-C Cribs Controlled Area to be spread by high winds, following a major range fire, beyond the present boundary. The contamination would be measurable, but low level and would signify an unacceptable lack of contamination control."

ARH-3088 provided this summary of the hazard resulting from the contamination in the BC Controlled Area:

> "At present, the radioactivity in the B-C Cribs Controlled Area is associated with rabbit fecal pellets on the ground surface. In addition, there is radioactivity in the sandy soil from four to nine inches deep as a result of radioactive urine and precipitation leaching radioactive materials from the pellets.(2) Additional radioactive material from the original source has not been detected since the burrow was covered. Although the soil is mainly sand, a heavy stand of shrubs, forbs, and grasses furnishes a buffer against surface winds.
>
> Analysis of vegetation samples taken from the affected area indicate background radioactivity containing only trace amounts of ^{90}Sr and ^{137}Cs, (Appendix B-1). Onsite air monitoring studies by Sehmel (Appendix B-3) indicates airborne ^{137}Cs is roughly 1/1,000,000 of the guide values for radiation workers (*AEC Manual*, Chapter 0524, "Standards for Radiation Protection") and is not significantly different than general onsite environmental surveillance data.
>
> For purposes of environmental management and planning for possible decontamination, the area has been divided into two zones according to the concentration of radioactive contamination present, (Appendix K-2). Zone A contains the most surface contamination and comprises approximately 560 acres with over 2,000 radioactive fecal pellets per acre. Aerial radiation surveys show surface contamination to be from one to ten micro curies per square meter. Zone B comprises approximately 2,000 acres* which contains a concentration of generally less than one micro curie per square meter of ground surface, (Appendix K-4). Total radioactivity on the ground surface and to a depth of 2.5 centimeters in Zones A and B is computed to be approximately 40 curies, of which 32 curies are ^{90}Sr and 8 curies ^{137}Cs, (Appendix B-4).
>
> Results of soil samples also indicate there is at least an equal amount of radioactivity below 2.5 centimeters to a depth of 20-30 centimeters (Appendix B-4), with cesium tending to remain nearer the soil surface and strontium to be separating and leaching downward.(2) Administrative control of the area during the past 13 years has been maintained without appreciable movement or spread of contamination and without detectable adverse effects to personnel, the public, or the environs. However, mechanisms which could make complete and finite control of the radioactivity difficult are as follows: (1) unauthorized entry into the zone by man, (2) biological transport mechanisms, (3) a major range fire through the area, (4) high velocity winds following a range fire, and (5) the effects of prevailing air currents.
>
> *Footnote: The total acreage within the perimeter of Zone "B" is approximately 2,000 acres. There are, however, approximately 500 acres scattered within Zone "B" that are free of contamination."

ARH-3088 reviewed the five mechanisms and concluded that the one with significant risk was the range fire. The reader is referred to the report for the details of the argument.

As mentioned above, ARH-3088 discusses two zones: A and B. Zone A is 560 acres of near-continuous contamination. This zone corresponds closely to the 0.59 to 0.88 $\mu Ci/m^2$ contours shown on the 1973 Cs-137 Aerial Survey (see Figure 2-7). Zone B circumscribes most of the 0 to 0.12 $\mu Ci/m^2$ area shown on the 1973 Cs-137 Aerial Survey. See Figure 2-16 for a representation of ARH-3088's Zone A and Zone B. Note that the workers had concluded that the 560-acre plot (Zone A) was essentially continuously contaminated, largely to a depth of 6 to 9 in. In discussing Zone A, "Cleanup of B-C Cribs Controlled Area" (Oberg 1973) noted that "The area contains an average frequency of about 2,000 radioactive droppings per acre. The radioactively contaminated soil around each dropping covers an average of one and a half square feet of surface with contamination and extends to a depth of nine inches. The frequency of droppings is such that it is impractical to decontaminate this area by a method other than complete stripping of the surface to a depth of nine inches."

The five different proposed action alternatives were as follows:

1. Provide fire protection only
2. Provide fire protection, vacuum 40 acres, strip 5 acres, leave the remainder of the area as is
3. Construct fire breaks and roads; scrape 100 acres of Zone A; vacuum clean 400 acres of Zone B; provide water plus power to the area; and leave the remaining acreage as is
4. Provide fire protection, water, and power; complete cleanup and release of all zones, and reestablish vegetation
5. Other proposals: plowing under the surface contamination; fixation of the soil surface against wind erosion; establishment of an ecological reserve.

ARH-3088's assessment of the alternatives is summarized in Table 2-2, "Evaluation of Alternatives Proposed by Maxfield in ARH-3088 (1974)."

Note that ARH-3088, in 1974, estimated the cost of scraping the 560 acres of continuous contamination, vacuuming the remaining scattered hot areas, and reestablishing the vegetation to be approximately $4.7 million.

2.4.4 Decision not to Clean the BC Controlled Area

In August 1974, ARHCO recommended to the AEC that, based on ARH-3088, there was no indication of undue risk to the public and employees and, therefore, no immediate action was necessary to decontaminate the area ("B-C Cribs Controlled Area" [Burton 1974]). In the letter to the AEC, ARCHO mentioned a proposed industrial security fence around the contaminated area, and the plan to put a water supply line to the controlled area to fight a fire, as well as some further efforts for fire and erosion control . In February 1975, the U.S. Energy Research and Development Administration wrote to ARHCO accepting its recommendation (see "B-C Cribs Controlled Area" [Elgert 1975]).

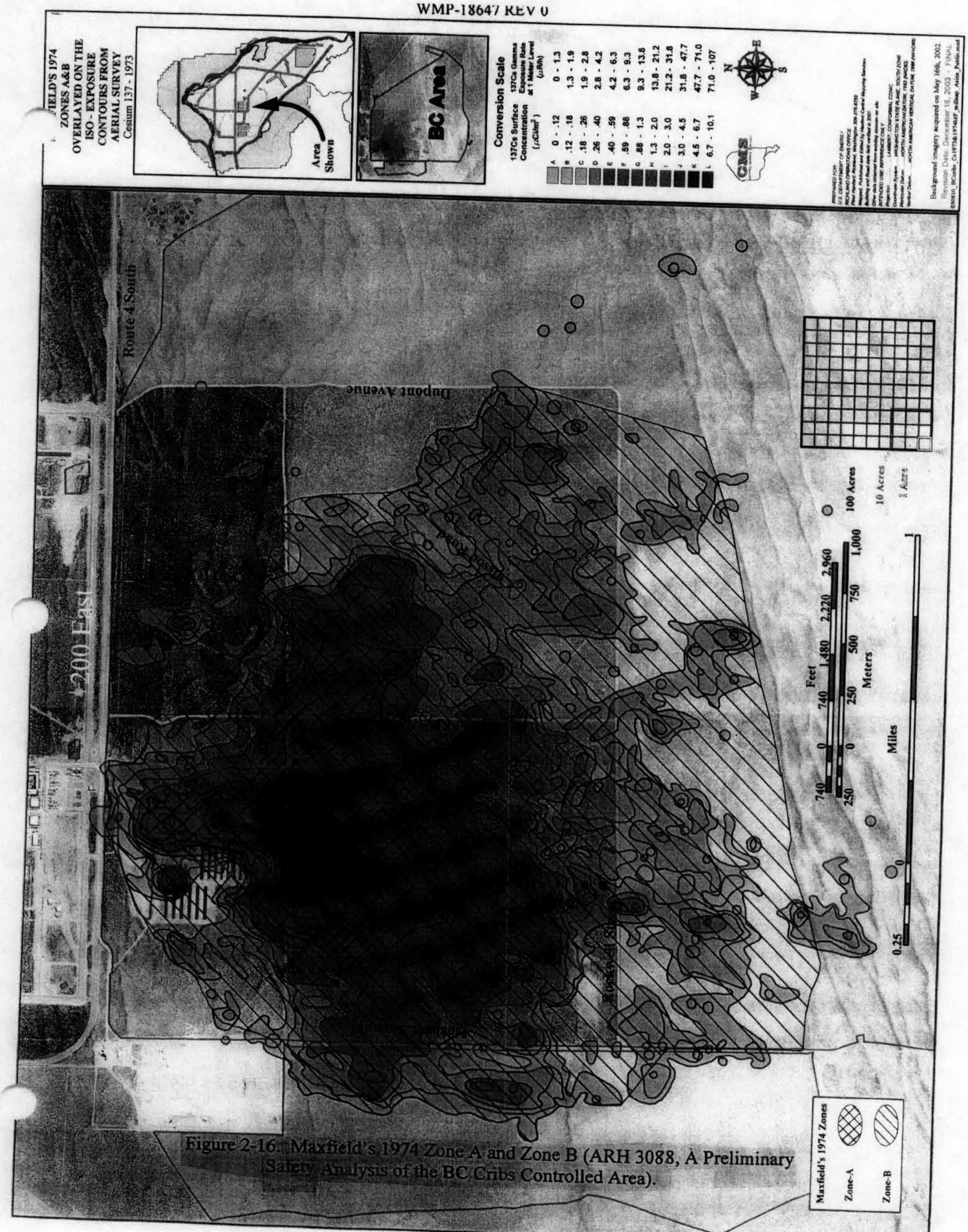


Figure 2-16. Maxfield's 1974 Zone A and Zone B (ARH 3088, A Preliminary Safety Analysis of the BC Cribs Controlled Area).

Table 2-2. Evaluation of Alternatives Proposed by Maxfield in ARH-3088 (1974).

Plan	Description	Percent Contamination Reduced	Percent Contamination Stabilized	Normal Operation: Increased Acres/Yr	Normal Operation: Onsite Movement Ci/Yr	Normal Operation: Offsite Release Ci/Yr	Accident Conditions: Increased Acres	Accident Conditions: Onsite Movement Ci	Accident Conditions: Offsite Release Ci	Conceptual Costs	Surveillance Costs/Yr
I	Control-as-is	0	0	0	None	None	4,000	24.0	4.0	$-0-	$5,000
II	Vacuum 40 acres; scrape 5 acres	2	2	0	None	None	3,920	23.5	3.88	170,000	5,000
III**	Vacuum 400 acres; scrape 100 acres	20	20	0	None	None	3,200	19.2	3.2	1,121,000	5,000
IV	Scrape and vacuum all acres	99	99	0	None	None	None	None	None	4,742,000	-0-
V	Plow and reseed or stabilize	0	90	0	None	None	400	2.4	0.4	1,000,000	5,000
VI	Set up ecological reserve	0	0	0	None	None	4,000	24.0	4.0	-0-	5,000

*All plans assume fire protection capability.

**The implementation of Plan III would reduce by 50 percent or more the chance of detectable contamination reaching and crossing Highway 4-S.

ARH-3088, 1974, *A Preliminary Safety Analysis of the B-C Cribs Controlled Area*, July 31, H. L. Maxfield, Environmental and Occupational Safety Section, Quality Assurance and Control Department, Operations Division, Atlantic Richfield Hanford Company.

2.5 CONTINUED BIOLOGICAL SPREAD FROM THE BC CRIBS AND TRENCHES

After the conclusions in 1975 that the major risk was from a range fire and that it was not warranted to clean up the site, the site entered a phase of routine monitoring. It soon became apparent that the contamination control measures instituted in the 1960s, although generally successful at inhibiting large-scale animal intrusion, were not entirely successful at controlling the biological spread of contamination, primarily through tumbleweeds growing on the cribs and trenches. For instance, during this period the asphalt pad that had been laid over part of Trench 216-B-28 in 1965 crumbled and became ineffective in preventing the growth of contaminated weeds and, maybe, animal intrusion. RHO-CD-673 noted that the blacktop had broken up.

"Decontamination of Roads in B-C Crib Control Zone" (Panesko 1978) noted that there was an increase in contamination on the roads in the BC Controlled Area and that there were indications of burrowing and contamination. The survey maps attached to this report indicated heavy weed growth over Trenches 216-53A, -53B, -54, and -58. The survey maps also indicated heavy contamination to the south of the cribs and to the east of the trenches. There was a note indicating that hot spots had been found in the sand dunes to the south of the firebreaks (as would be expected from the aerial surveys).

RHO-LD-79-75, *Environmental Protection Annual Report – CY 1978*, noted that in 1979 a plan was being prepared to clean up and stabilize the BC Cribs, Trenches, and Controlled Area. At that time, it was expected that 50 percent of the controlled area would be completed by 1981. By 1980, Rockwell Hanford, as evidenced by the report "Environmental Evaluation Plan for Stabilization Activities Associated With B-C Crib Site" (Rockwell Hanford 1980), still was considering stabilizing not only the cribs and trenches themselves, but also the contaminated area within the firebreaks (the controlled area).

In 1978, apparently as part of a plan to monitor the BC Controlled Area, an aerial survey was performed; see EGG-1183-1828. This survey shows the same general pattern of contamination that the 1973 survey showed and gives no indication of large-scale movement of activity. The Cs-137 iso-exposure contours are shown in Figure 2-8. For an overview of the BC Cribs at that time, see Figure 2-17.

As further evidence of the concern over the spread of contamination, "Second Quarter Fiscal Year 1981 Report of Radiological Surveys" (Conklin and Osborne 1981a) included this statement in the cover memo:

> "The B-C Cribs area should be considered a high priority item, because of increased contamination, and the migration of the contamination away from the trenches and cribs. It is recommended that stabilization be considered as soon as possible, that surveys of the area be increased from semi-annual to quarterly, and that additional plots and air samplers be considered to better monitor contamination in the area."

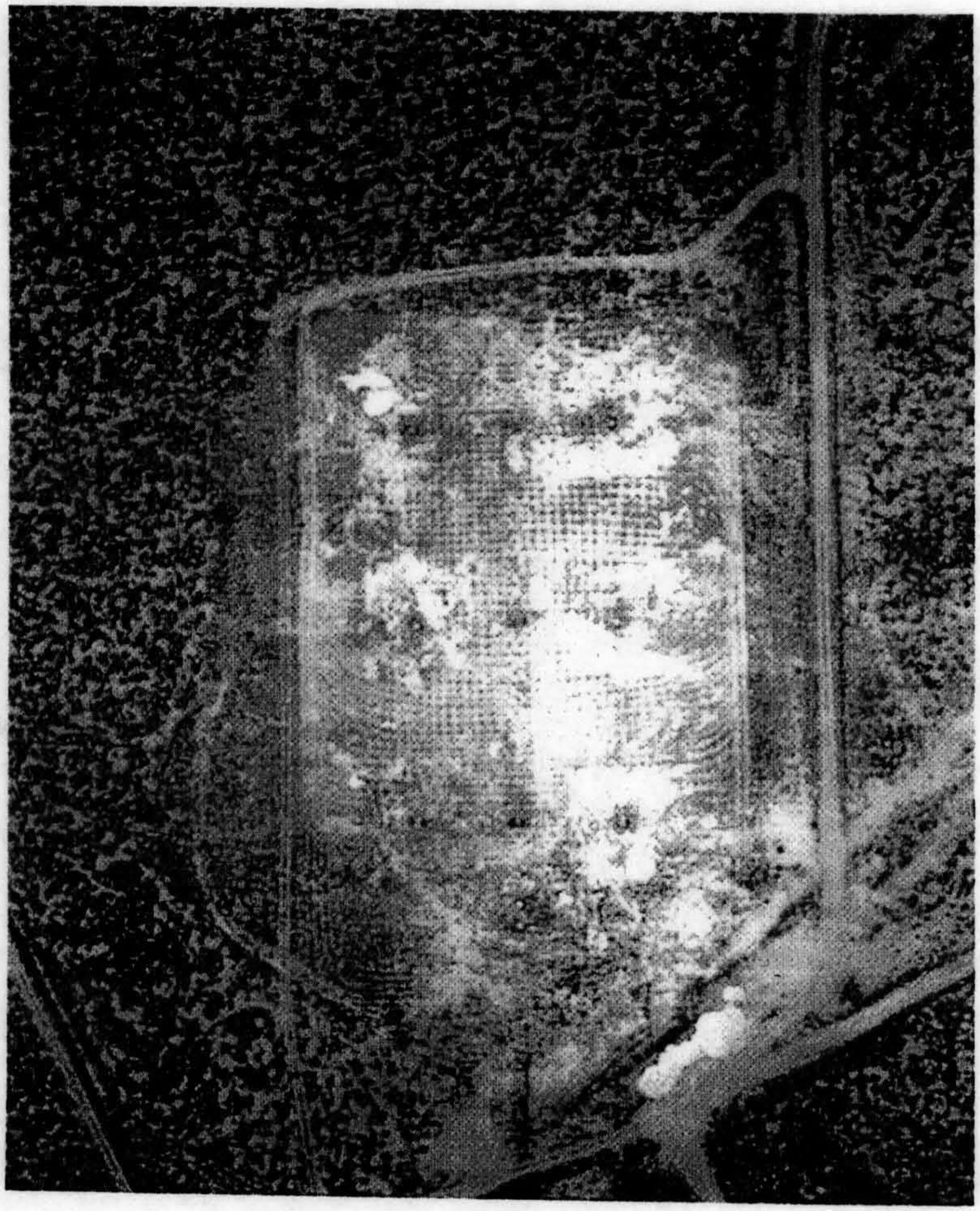


Figure 2-17. BC Cribs, 1980.

In the details of the report, Conklin noted that spotty contamination ranging from 20,000 to 900,000 disintegrations per minute (dpm) beta-gamma was detected throughout the trench area. This contamination had not been detected in previous surveys and was taken to be an indication that erosion of the trench soil cover was uncovering more contamination. A buried component in the northeast corner of the trench area, apparently from the aboveground waste distribution system, was discovered and removed; this component was reading about 500 mR/h. This resulted in a recommendation that the route of the old transfer line be examined to ensure that there were no further undocumented burials. Conklin also noted that contamination on the survey plots established in 1979 had been variable and this was thought to indicate a movement of contamination, particularly in the prevailing wind direction (toward the southeast). Conklin's report included maps showing the increase in contamination.

In his letter, "Summary of B-C Crib Area Contamination Characterization," Conklin (1981) reviewed the contamination over the trenches since about 1974 and drew attention to the steadily increasing weed growth over the trenches. He noted that in 1977, a survey showed the spread of tumbleweeds to the east of the trenches.

A radiation survey in July 1981 (T81 0930, "Surveillance of Surface Contamination Areas in BC Cribs") showed extensive contamination all over the area of the trenches and including the area to the east of the lower trenches. This report noted large areas of contamination on the broken asphalt, possibly brought up by tumbleweeds; contaminated roots and tumbleweed fragments were found and they were thought to have been left behind by weed removal activities.

The "Third Quarter Fiscal Year 1981 Report of Radiological Surveys" (Conklin and Osborne 1981b) noted that the BC Controlled Area north of the cribs was found to be grossly contaminated with blown-in tumbleweeds. Occurrence Report number 81-38, "Contamination was Found Outside the Radiation Controlled Area," had been issued and cleanup was underway at the source, which was the northeast portion of the trench area.

Thus, from this discussion, it can be seen that by the late 1970s and early 1980s, the stabilization measures that had been taken in the 1960s had failed and contamination was spreading, primarily due to contaminated tumbleweed.

2.6 STABILIZATION OF THE BC CRIBS AND TRENCHES IN 1982

WFH-81-057, "BC Crib/Trench Area" (Heine 1981), discussed the problem of the increase and movement of contamination in the BC Cribs and Trenches Area. Heine mentioned that tumbleweed had been removed from the area and a herbicide had been applied. There were plans to add additional rock cover to Trenches 216-B-20, -21, and -22. Heine also mentioned plans to scrape the surface of the area that generally was contaminated and place this soil into a borrow pit to the south of the trenches. (Note that this is the only mention found of a contaminated borrow pit to the south of the trenches. Some support for the existence of such a borrow pit comes from the soil samples taken and reported in the 1978 environmental report [RHO-LD-79-75]: the only elevated sample from ten taken around the controlled area was one "located in a sandy area south of the 216-B-28 trench"). There also is discussion of an approved plan to stabilize the BC Cribs (but apparently not the BC Trenches) Area.

"Radiological Survey Report for the Second Quarter of Fiscal Year 1982" (Wheeler 1982) reported that no contamination was found on the stabilized cribs and trenches, but spotty contamination was reported on those areas of the trenches not yet stabilized.

John Winterhalder, who wrote the plans for the operators who did the work of the 1981-1982 stabilization, said that the stabilization was carried out under the Radiological Area Reduction Program under Bill Heine (see Appendix A). Winterhalder reported that a weighted piece of earthmoving equipment was driven over the cribs and trenches looking for weak spots before the stabilization began; no weak spots were found. Cover soil was taken from the area just to the north (now designated 200-E-49). The entire area of the cribs and trenches was covered with about 2 ft of soil and then reseeded with vegetation of a sort designed to resist tumbleweed growth. Winterhalder said that after the immediate area of the cribs and trenches had been completed, there was considerable discussion about what to do with the surrounding contaminated area (the BC Controlled Area roughly within the firebreaks). There was discussion about stripping the land and then recovering it with soil and plants. It was decided that this would not be a good idea, because the radionuclides in this area were not spreading. Thus, it was decided to leave the BC Controlled Area alone (as was the case in 1974) and to work to control the source of contamination (the cribs and trenches proper). See Figures 2-18 and 2-19.

RHO-HS-SR-83-13, *Rockwell Hanford Operations Environmental Surveillance Annual Report, Calendar Year 1983*, noted:

> "Surveys of the cribs and trenches up to 1981 found that general contamination, primarily from tumbleweeds, was present. Corrective action was initiated in 1981 to surface stabilize the Cribs and Trenches 216-B-21, -22, -23, -27, and -28, as well as remove most of the contamination from the remainder of the trenches. Cleanup of the controlled area was also begun at that time.
>
> In 1982, surface stabilization of the cribs and trenches was completed and an additional portion of the controlled area was cleaned and released unconditionally from Radiological Controlled Area posting. The progress of the work performed in this area is illustrated in Figure 44.
>
> Since completion of the stabilization, no contamination has been detected on the cribs or trenches."

Thus, the stabilization was completed in 1982 and was judged to be effective, at least during the period immediately afterwards.

2.7 ROUTINE MONITORING AND CONTROL OF THE BC CRIBS AND TRENCHES

After the stabilization in 1981 and 1982, the area entered a long period of routine monitoring and control, with some exploratory surveying taking place.

Figure 2-18. BC Cribs and Trenches During Stabilization, 1982.

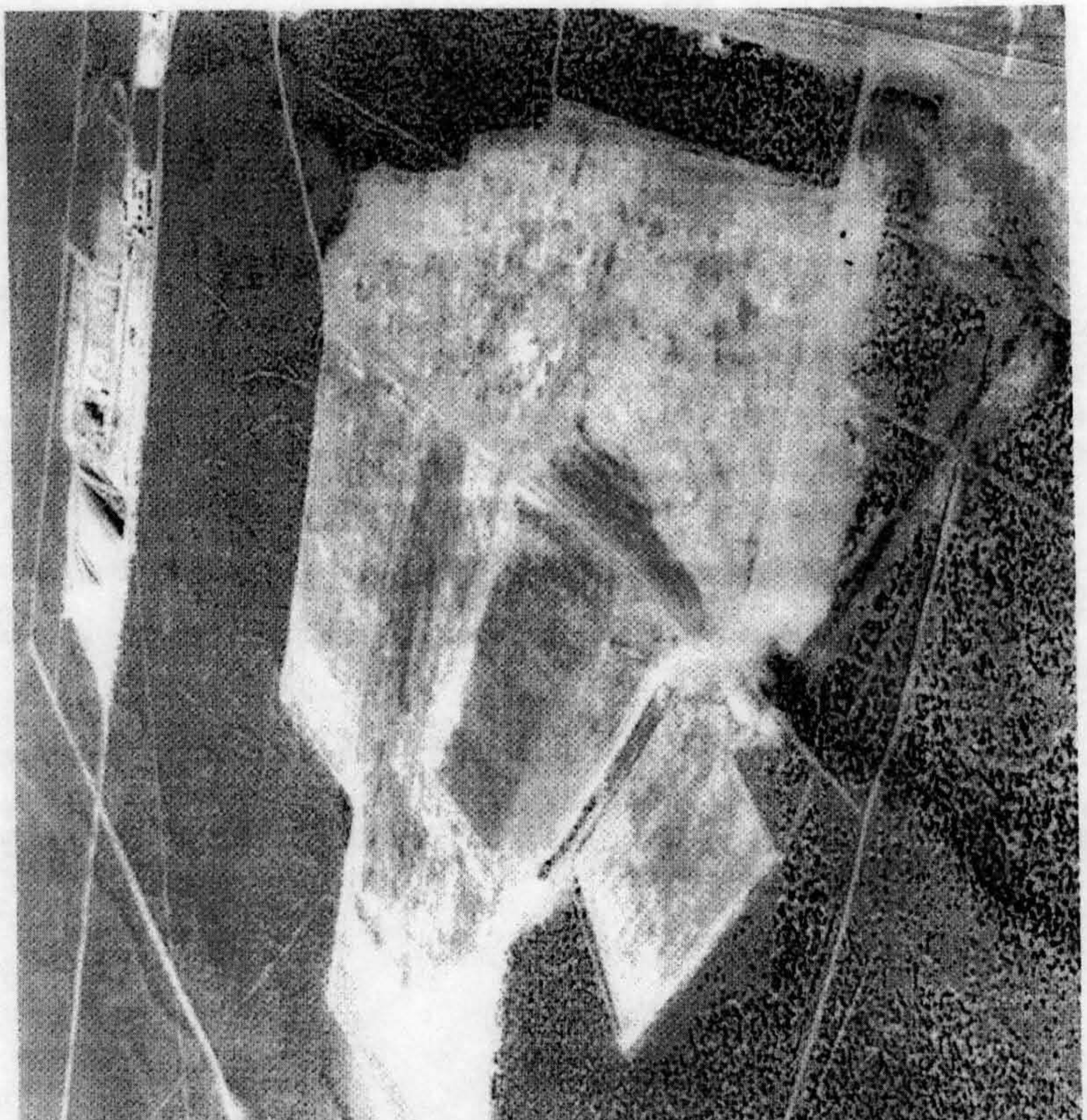


Figure 2-19. BC Cribs and Trenches After Stabilization, 1983.

The "Semiannual Radiological Survey Summary for the Second Half of Fiscal Year 1984" (Wheeler 1984) mentioned spotty contamination to 10 mrad/h on the firebreaks. The report also mentioned that in September 1984, after a range fire, spot surveys were conducted to the east and south of the firebreak areas with the road monitor (a tractor with radiation detectors mounted on it). Contamination was found throughout the areas surveyed. The map with the report showed contamination found well east (approximately 0.8 mi) of the intersection of Dupont Avenue and Rockwell Street; it also reported a large area of contamination into the dunes area well south (approximately 0.8 mi) of Rockwell Street. The airborne surveys show contamination in these general areas. The report also records extensive spotty contamination to 60 mrad/h in a burned area at the intersection of Rockwell Street and Dupont Avenue. Cleanup of this area was attempted, but the contamination was found to be too extensive; the contamination was reported to have leached to 3 ft deep. A. W. Conklin also mentioned the attempt to clean up this area (see Appendix A). Conklin reported that the soil was removed using shovels and 5-gal buckets, and after about 50 buckets, the workers gave up, because the contamination was deep into the soil and seemed to be getting more active as they dug deeper. Conklin also noted that this area did not show up on the airborne surveys as being contaminated; he speculated that this was because the contamination was primarily Sr-90 and would not be detected by the aerial survey (because Sr-90 and its daughter have only very low-intensity gamma and X-ray emissions). Conklin also mentioned the surveys in the area to the east of Dupont Avenue in 1984. He recalled that fairly dense, spotty contamination (e.g., about 1 spot per 10 ft^2) was found in some areas and some contamination was found near the present soil contamination area boundary. W. L. Osborne and W. M. Hayward also mentioned the effort to decontaminate the small burned area and confirmed that large amounts of contaminated soil were found and the effort was abandoned (see Appendix A).

An airborne photograph of the BC Cribs and Trenches Area in 1987, well after the stabilization, is given in Figure 2-20.

In July and August 1988, another aerial survey of the BC Area was made (EGG-10617-1062, *An Aerial Survey of the Hanford Site and Surrounding Area, Richland, Washington [Date of Survey: July-August 1988]*). This aerial survey shows essentially the same contaminated area that was shown on previous aerial surveys; there was no indication that the bulk of the radioactive material had moved at all. See Figure 2-21.

In 1990, Radiological Problem Report N-023-90, "600 Area/BC Crib Controlled Area," was written on the results of two special surveys: (1) one of the area to the west of Isochem Avenue and just south of the U.S. Ecology site, and (2) one of the area just south of the trenches across ARCHO Street. This Radiological Problem Report reports finding contamination in both of these areas. The contamination to the south of the U.S. Ecology site was evident as far back as 1973, because it is shown both on the aerial surveys and the jackrabbit pellet survey. The contamination reported to the south of the trenches (to 800,000 dpm) is in the middle of the most contaminated area as shown by all of the aerial surveys. The Radiological Problem Report was written because the area was not posted. The rediscovery of these contaminated areas points to a loss of knowledge of the site history.

Figure 2-20. BC Cribs and Trenches Area, 1987.

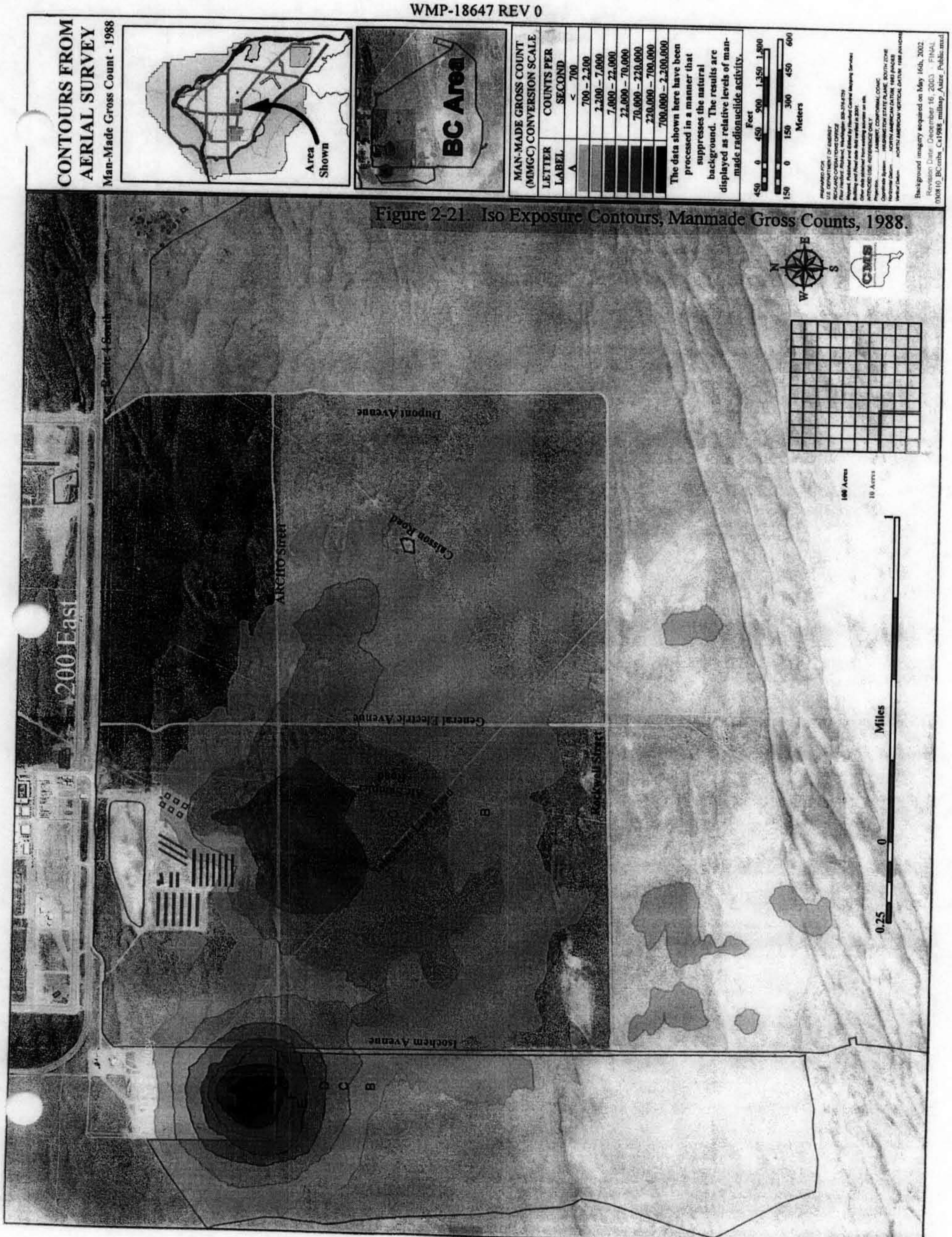


Figure 2-21. Iso Exposure Contours, Manmade Gross Counts, 1988.

In 1992, WHC-EP-0145-4, *Westinghouse Hanford Company Environmental Surveillance Annual Report—200/600 Areas, Calendar Year 1990*, Section 7.7, "BC Cribs and Controlled Area," concluded that there had been no significant migration of contamination from the cribs and trenches because they were stabilized 10 years earlier in 1982. WHC-EP-0145-4 states the following: "In 1979 special survey plots were established throughout the controlled area to monitor for migration of the contamination. Data accumulated during the 10-year period indicates that no significant migration away from the area has occurred. The cribs and trenches (approximately 50 acres) were surface stabilized in 1982 and are surveyed semiannually with the MSCM [mobile surface contamination monitor] tractor."

In 1996, another aerial survey was done of the site. The results of this survey never were completely analyzed and only preliminary results are available. The iso-exposure contours for Cs-137 are shown in Figure 2-22. Again, this survey shows the same basic pattern as the previous airborne surveys and confirmed that the contamination has not moved significantly.

Thus, the monitoring during this period shows that the stabilization of the cribs and trenches in 1982 was successful in controlling the biological spread of contamination and that the large areas of soil contamination have remained fixed.

2.8 LARGE EXPANSION OF THE BC CONTROLLED AREA IN 1997 AND SUBSEQUENT EFFORTS TO REDUCE IT

2.8.1 Expansion of the BC Controlled Area

In October 1996, Bechtel Hanford, Inc. (BHI), assumed responsibility for the BC Controlled Area and kept control of the area until responsibility was transferred to Fluor Hanford in October 2002. In October or early November 1996, the area to the east of the firebreak roads, i.e., to the east of Dupont Avenue, was surveyed and found to be radioactively contaminated in spots. This was reported to the U.S. Department of Energy, Richland Operations Office and resulted in the filing of an occurrence report (see RL-BHI-DND-1996-0023, Final Report, *Legacy Contamination Discovered Outside a Radiologically Controlled Area*). By late January or early February 1997, additional surveys had been completed and the present Soil Contamination Area established. W. L. Osborne reported (see Appendix A) that the U.S. Department of Energy, Richland Operations Office determined that they either had to post every contaminated spot found or post a larger area containing the contaminated spots as a soil contamination area; they chose to post a larger area bordered by Army Loop Road for convenience. This action expanded the posted area associated with the BC Cribs and Trenches from about 4 mi^2 to 13.4 mi^2.

BHI-01017, *Environmental Radiological Compliance Surveys for 1997 Performed in Support of the Radiological Area Remedial Actions Project (RARA) of Bechtel Hanford, Inc.*, reported these nonroutine radiological surveys and provided survey maps in Appendix B to the report. These survey maps show a considerable number of contaminated spots to the west of Isochem Avenue and to the south of the U.S. Ecology site, as well as some spots east of Dupont Avenue and southeast of the firebreak roads. One map shows roadway spots that were found and removed.

WMP-18647 REV 0

Figure 2-22. Preliminary Contours from Aerial Survey, Cesium-137, 1996.

See Figures 2-23 and 2-24. BHI-01145, *Radiation Area Remedial Action FY 1997 Summary Report*, provides a map of the BC Controlled Area before and after the expansion.

BHI-01202, *Data Quality Objectives Summary Report for the 200 B/C Controlled Area Reposting*, contains this statement about these surveys:

> "In 1996, an off-normal report was issued that indicated the presence of contamination outside the 4-square mile controlled area. Total contamination at levels up to 30,000 disintegration per minute (dpm) beta/gamma was found in eight areas. The contamination was believed to be the product of legacy waste from the 200 B/C Cribs that migrated to adjacent areas south of the crib area through animal and vegetation intrusion. The posted area was increased to approximately 12 square miles total, with the southern boundary being the Army Loop Road. This southern boundary was chosen mainly because of the convenient access provided for further monitoring and to control access by authorized site personnel.
>
> In 1997 and 1998, surveys were made of limited areas with both tractor mounted beta/gamma detector system and hand carried Geiger-Mueller probes. Areas directly over the surface of the crib area and along two firebreak roads were surveyed. Measurable low-level contamination was found to the west and south of the crib area and also to the east and south of the crib area. Two additional spots of total contamination estimated to be 1 K to 10 K counts per minute (cpm) were found and decontaminated on the northern bank of the Army Loop Road, the southern boundary of the posted area."

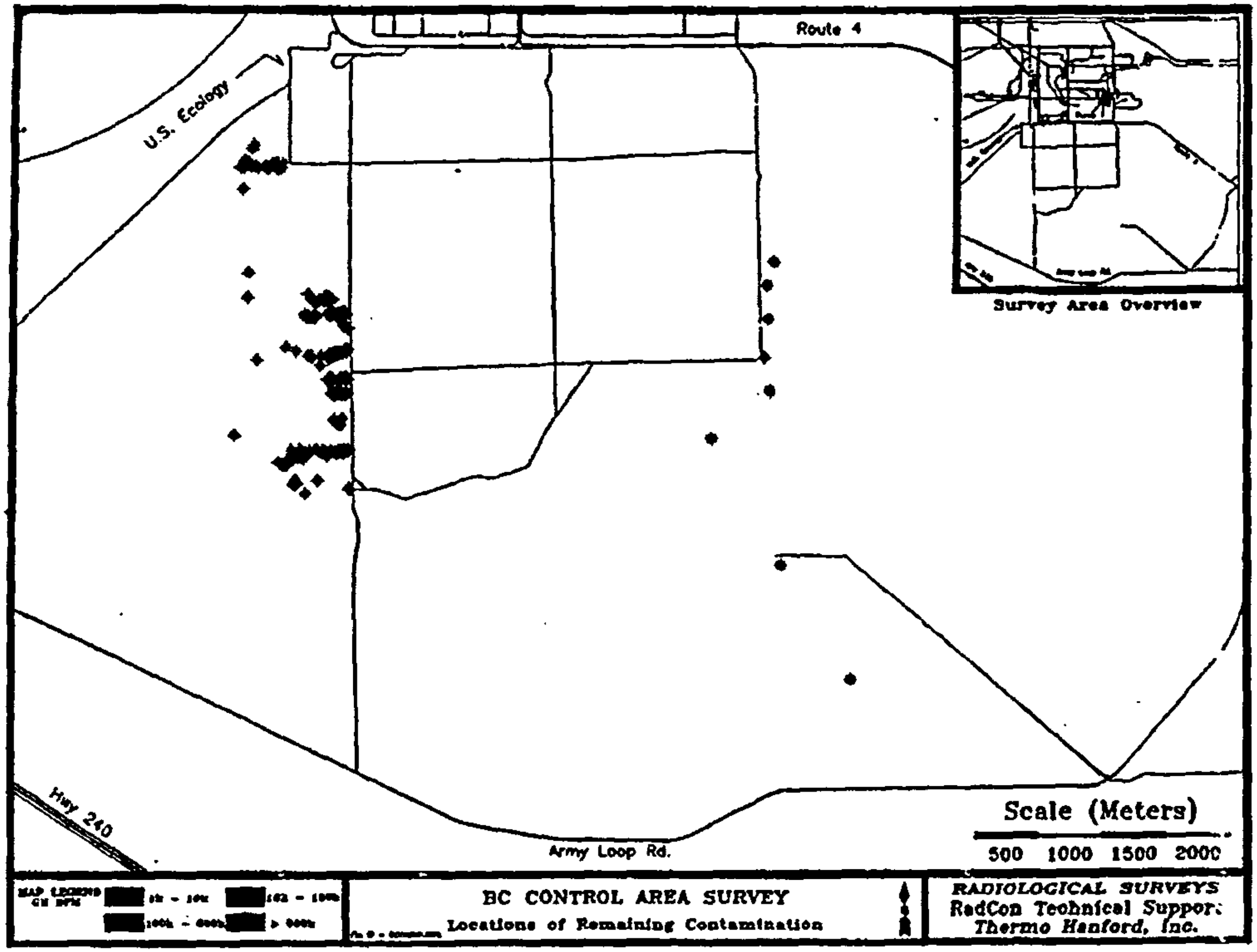
Efforts to find copies of the original survey reports for this work have failed; they have not been found in the normal record system for surveys and none of the principals contacted had copies.

2.8.2 Efforts to Reduce the Size of the BC Controlled Area

Soon after the expansion of the BC Controlled Area, BHI undertook a process, based on the U.S. Environmental Protection Agency's (EPA) data quality process, to survey the expanded soil contamination area and to remove the posting over a large part of it.

The first step in this process was to develop the data quality objectives for the survey. BHI-01202 contains the data quality objectives for the surveys. It was concluded, based on the definition of a soil contamination area at the time, that a two-part survey would be needed in order to remove the posting: (1) one part to determine the transferable levels of the contamination, and (2) a second part to calculate the doses to individuals occupying the areas. The transferable contamination levels were required to be below a pre-determined level, and the doses, calculated using RESidual RADioactivity (RESRAD), were required to be less than 15 mrem/yr based on EPA practice. (It should be noted that the definition of a soil contamination subsequently has been changed, and dose calculations no longer are needed to determine whether or not an area is a soil contamination area.) The transferable surveys were to be done first, and the soil samples would be taken only if the transferable limit was met.

Figure 2-23. BC Control Area Survey: Locations of Remaining Contamination.



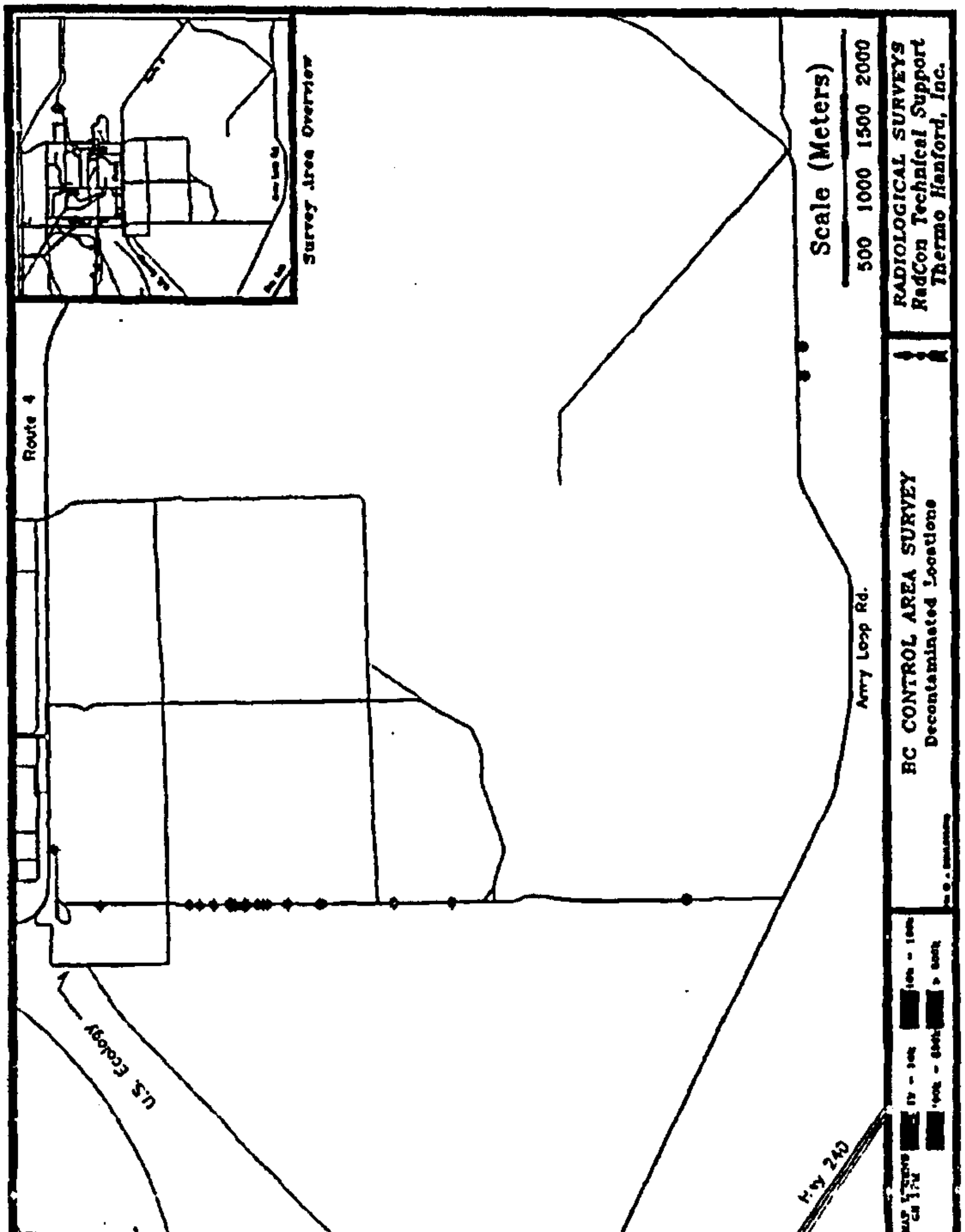


Figure 2-24. BC Controlled Area Survey: Decontaminated Locations.

BHI-01225, *Sampling and Analysis Instruction for the 200 B/C Controlled Area Reposting*, contains the sampling and analysis plan for the survey. BHI-01319, *Data Assessment Report for the Sampling and Analysis Activities Conducted to Support Reposting the 200 B/C Soil Contaminated Area*, discusses the results of the survey and sampling activities. The report contains this summary:

> "The 200 B/C Site is a soil contamination area that has been incrementally designated as a controlled access area over a period of approximately 40 years. A data quality objectives process was used to define the data needs to more accurately reflect the areas that pose a potential risk to site workers and visitors, with the ultimate goal of reposting those areas that do not require controlled access. Based on the results of the data quality objectives process, a sampling and analysis instruction and a task instruction were written to direct the collection of data to support any reposting decision. Field activities that were implemented generally followed or exceeded the sampling and analysis instruction and task instructions. Any changes were approved by the Project Engineer.
>
> For purposes of the site investigations, the 200 B/C Controlled Area was divided into two strata. Stratum A includes the areas adjacent to the cribs, which were anticipated to have higher contamination levels. Stratum B encompasses the remainder of the controlled area. The sampling program included two phases:
>
> Phase I consisted of transect surveys, which were used to identify locations of elevated radionuclide concentrations. These results were used to select sites to sample for analysis of transferable contamination. Phase I results indicated that transferable concentrations in both strata exceeded the transferable criteria.
>
> Phase II studies were designed to evaluate the dose levels from the two strata. Based on the results of Phase I survey analyses, it was determined that Phase II sampling was not justified. Sampling was conducted at the request of the U.S. Department of Energy, however, to evaluate contamination in the cryptogamic layer, a surface soil layer that is composed primarily of lichens, mosses, and algae. Comparison of soil contamination with cryptogamic data from the same location showed no difference in concentrations of radionuclides in the two media.
>
> The results of the transferable contamination measurements do not support reposting of any portion of the 200 B/C Controlled Area at this time. Qualitative dose assessments based on gamma survey measurements indicate that the potential dose to a worker or visitor is likely less than 1 mrem/yr."

Thus, the effort to remove the soil contamination area posting over most of the BC Area failed due to the level of transferable contamination found using a procedure developed for this purpose. Because the transferable surveys failed, no soil samples were taken.

The results of the transect survey that was performed are given in Figure 2-25. This survey was patterned after the 1972 jackrabbit pellet survey (see Figure 2-14) and essentially confirmed the results of this survey, because both show about the same distribution of activity in the area of high activity.

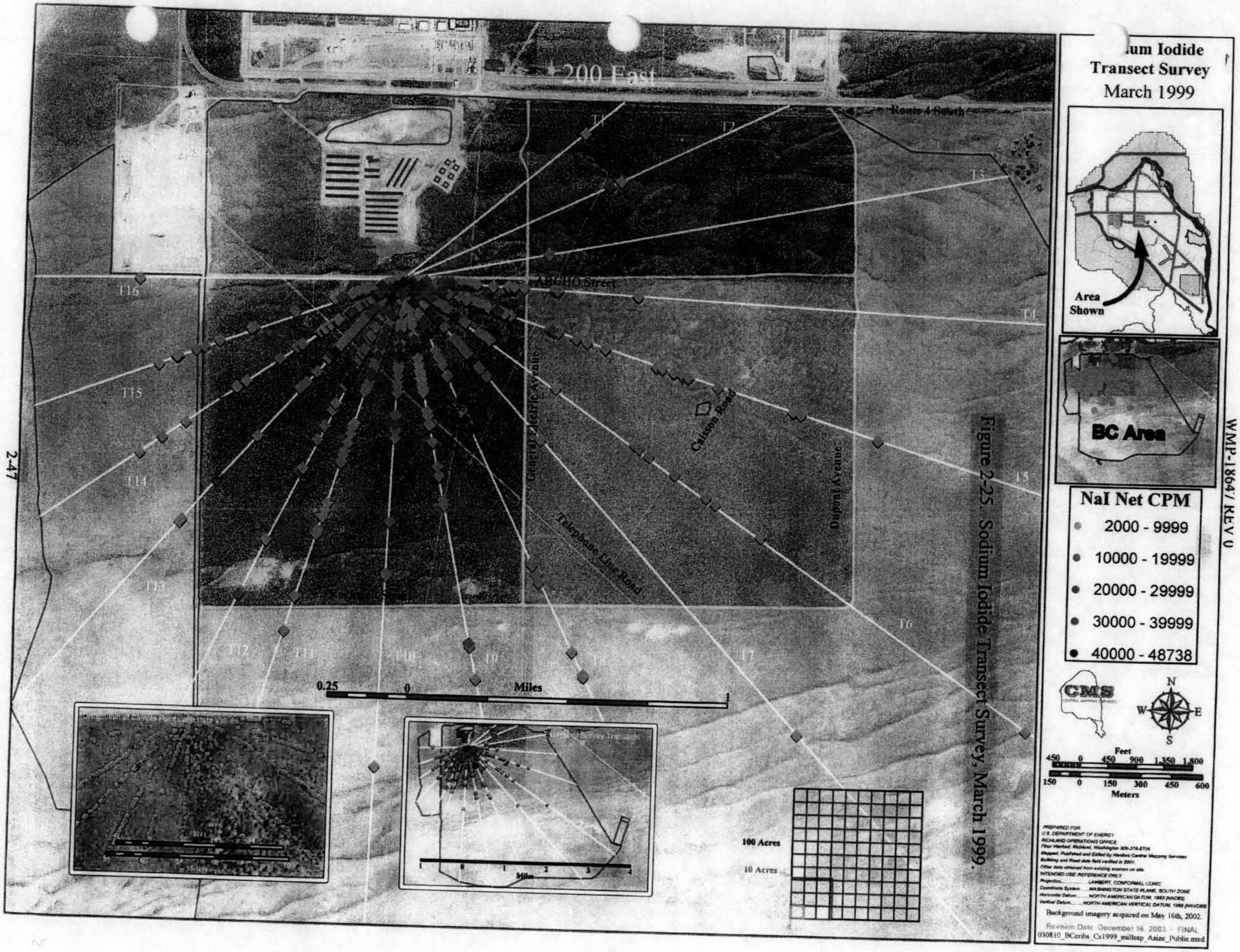


Figure 2-25. Sodium Iodide Transect Survey, March 1999.

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3.0 REVIEW OF INFORMATION PERTINENT TO THE CONCEPTUAL MODEL OF THE RADIOACTIVE CONTAMINATION

The chronological narrative in Chapter 2.0 provides the historical perspective needed in order to understand the present condition of the BC Area and discusses many of the sources of information useful for ultimately establishing a conceptual model for the contamination spread, so that a well-grounded survey plan can be developed. This chapter gives a more detailed review of the specific radiological information of use contained in these sources, as well as useful information from other sources. The intent of this chapter is to develop the specific radiological information upon which conceptual site models can be based; these models are discussed in Chapter 4.0.

3.1 INITIAL QUANTITY OF RADIOACTIVE MATERIAL IN THE BC CRIBS AND TRENCHES

The summaries of the radionuclide inventories given below are taken from RHO-CD-673. For the details on each crib and trench, please consult this reference. It should be noted, however, that "Status of BC Crib Surface Contamination Development Work" (Bruns 1974a) reported the following radionuclides in high-activity surface soil in the BC Area in 1974. The primary radionuclides were Cs-137 and Sr-90; others present in some abundance were Pu-239/240, Eu-155, Co-60, and Am-241. Others found in smaller quantities were Eu-154, U-238, U-235, Ru-103, Pu-238, Ru-106, Rh-106, Co-57, Sb-125, Ra-226, Cr-51, Sr-85, Eu-152, Cs-135, Ce-141, Th-228, K-40, and Ra-228. Thus, the summaries given in RHO-CD-673, although they probably contained the primary nuclides, certainly did not contain all the nuclides that were buried. Recent efforts to calculate (by modeling) the quantities of the total spectrum of radionuclides disposed of to these cribs and trenches are beyond the scope of this report.

In Tables 3-1, 3-3, and 3-4, the amount of uranium given for June 30, 1978, exceeds the amount of uranium at the time of discharge. This is consistent with the original reference (RHO-CD-673), and the reason for the inconsistency is not known. The term "at the time of discharge" is used in the original reference and is believed to refer to the time that the waste was discharged to the ground.

3.1.1 Cribs 216-B-14 to -19

These cribs were active between January 1956 and December 1957. They received a total of 3.90×10^7 L of waste (1.03×10^7 gal) (see Table 3-1, "Radionuclide Content of Cribs 216-B-14, -15, -16, -17, -18, and -19").

3.1.2 Trenches 216-B-20 to -22

These trenches were active between August 1956 and October 1956. They received a total of 1.41×10^7 L of waste (3.72×10^6 gal) (see Table 3-2, "Radionuclide Content of Trenches 216-B-20, -21, and -22").

Table 3-1. Radionuclide Content of Cribs 216-B-14, -15, -16, -17, -18, and -19.

Radionuclide	At Time of Discharge	As of June 30, 1978
Pu, g	70	70
Beta, Ci	327000	4347
Sr-90, Ci	1850	1082.2
Ru-106, Ci	118350	0.033
Cs-137, Ci	1840	1116
Co-60, Ci	26	1.49
U, kg	1410	1415

Source: RHO-CD-673, 1979, *Handbook-200 Area Waste Sites*, H. L. Maxfield, Richland, Washington, April 1.

Table 3-2. Radionuclide Content of Trenches 216-B-20, -21, and -22.

Radionuclide	At Time of Discharge	As of June 30, 1978
Pu, g	13.9	14.2
Beta, Ci	174000	4515
Sr-90, Ci	1940	1128
Ru-106, Ci	55000	0.014
Cs-137, Ci	1915	1158.1
Co-60, Ci	23.9	1.34
U, kg	1450	1445

Source: RHO-CD-673, 1979, *Handbook-200 Area Waste Sites*, H. L. Maxfield, Richland, Washington, April 1.

3.1.3 Trenches 216-B-23 to -28 and -52

These trenches were active between October 1956 and January 1958. They received a total of 3.69×10^7 L of waste (9.74×10^6 gal) (see Table 3-3, "Radionuclide Content of Trenches 216-B-23, -24, -25, -26, -27, -28, and -52").

3.1.4 Trenches 216-B-29 to -34

These trenches were active between June 1957 and October 1957. They received a total of 2.84×10^7 L of waste (7.50×10^6 gal) (see Table 3-4, "Radionuclide Content of Trenches 216-B-29, -30, -31, -32, -33, and -34").

Table 3-3. Radionuclide Content of
Trenches 216-B-23, -24, -25, -26, -27, -28, and -52.

Radionuclide	At Time of Discharge	As of June 30, 1978
Pu, g	39.3	39.8
Beta, Ci	336000	6848
Sr-90, Ci	2361	1382.85
Ru-106, Ci	108800	0.046
Cs-137, Ci	1643	1552.5
Co-60, Ci	49	2.78
U, kg	1820	2207.9

Source: RHO-CD-673, 1979, *Handbook-200 Area Waste Sites*, H. L. Maxfield, Richland, Washington, April 1.

Table 3-4. Radionuclide Content of Trenches 216-B-29, -30, -31, -32, -33, and -34.

Radionuclide	At Time of Discharge	As of June 30, 1978
Pu, g	28.7	28.5
Beta, Ci	112400	6207
Sr-90, Ci	1342	799
Ru-106, Ci	34400	0.018
Cs-137, Ci	3904	2389.9
Co-60, Ci	15.2	0.95
U, kg	664	670

Source: RHO-CD-673, 1979, *Handbook-200 Area Waste Sites*, H. L. Maxfield, Richland, Washington, April 1.

3.1.5 Trenches 216-B-53A, -53B, -54, and -58

These trenches were active between November 1962 and June 1967. They received a total of 1.98×10^6 L of waste (5.22×10^5 gal) (see Table 3-5, "Radionuclide Content of Trenches 216-B-53A, -53B, -54, and -58").

3.1.6 Aboveground Piping Burial Trench

As reviewed in Section 2.2.6, the aboveground transfer piping was buried in a shallow trench, 3 to 4 ft deep, between Trenches 216-B-29 and 216-B-53A. Because this pipe showed up as a distinct hot spot on the aerial gamma surveys of 1973 (EGG-1183-1661) and 1978

(EGG-1183-1828), it is likely that it is heavily contaminated with the same radionuclides that were buried in the trenches. The approximate location of the pipe burial trench is shown on Figure 2-2.

Table 3-5. Radionuclide Content of Trenches 216-B-53A, -53B, -54, and -58.

Radionuclide	At Time of Discharge	As of June 30, 1978
Pu, g	116.7	116.7
Beta, Ci	2553	56.7
Sr-90, Ci	20.2	14.47
Ru-106, Ci	26	0.004
Cs-137, Ci	14.9	10.90
Co-60, Ci	4	0.77
U, kg	50.3	49.96

Source: RHO-CD-673, 1979, *Handbook-200 Area Waste Sites*, H. L. Maxfield, Richland, Washington, April 1.

3.1.7 Other Buried Equipment

A distinct hot spot in the northeastern portion of the trenches area on the aerial gamma surveys of 1973 (EGG-1183-1661) and 1978 (EGG-1183-1828) subsequently was discovered by survey crews in 1981. This hot spot was found to be due to buried, highly contaminated equipment that apparently was used in the aboveground piping system. The equipment was removed and disposed of in a burial site. "Second Quarter Fiscal Year 1981 Report of Radiological Surveys" (Conklin and Osborne 1981a) recommended that the route of the aboveground piping be surveyed with a metal detector to determine if any further equipment was buried. No record of such a survey has been found.

3.1.8 Summary Discussion

It can be seen from a review of the information in this section that the primary long-lived radionuclides of concern are Cs-137 and Sr-90. Other nuclides likely to be present are Pu-239/240, Co-60, Am-241, and uranium. Other nuclides, many with short half-lives, that would need to be assessed for membership in a list of radionuclides of concern, are Eu-154, Ru-106, Eu-155, Rh-106, Co-57, Sb-125, Cr-51, Sr-85, Eu-152, Cs-135, Ce-141, Th-228, K-40, and Ra-228. Also present is some contaminated piping at one location. There is a possibility that there is buried piping and/or equipment in other locations. The radionuclides of concern are considered in detail in Section 3.6.

3.2 INITIAL AREAL SPREAD OF THE RADIOACTIVE MATERIAL BY ANIMALS

As discussed above, the initial spread of contamination took place by animal intrusion into the cribs and trenches, to a substantial degree Trench 216-B-28. The animals ingested the salt and then urinated and defecated over a substantial area to the east, south, and west of the BC Cribs and Trenches Area. Much of the spread was stopped in 1965 when an asphalt pad was poured over Trench 216-B-28 (see Figures 2-9 and 2-10); most of the remaining spread was stopped in 1969 when the remaining trenches were covered with gravel and sand. "B-C Crib Unplanned Radioactivity Release Cleanup" (Bruns 1972) noted: "The present contaminated area is about 4 square miles, but the spread since covering the animal burrows to the cribs about eight years ago has been minimal." Two substantial surveys were completed in the early 1970s to delineate the extent of the contamination.

3.2.1 Rabbit Pellet Distribution Survey

An initial effort to determine the contaminated area was completed by Battelle-Northwest Laboratories in 1972 and 1973 and reported in BNWL-1794 and "Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation" in *Health Physics*. In this survey, ecologists using compasses walked transect lines and stopped every 20 paces and measured the contamination level on the ground around them using Geiger-Mueller detectors. The results of the survey are shown in Figures 2-14 and 2-15. A good summary of the work is given in the abstract to BNWL-1794.

> "During 1972 and 1973 a study was conducted in the B-C Cribs, 200 East Area, to learn the extent to which jackrabbits (Lepus californicus) and their predators had dispersed buried radioactive wastes in their fecal pellets and scats. The specific objective was to gather sufficient data on the pattern of dispersal so that statistically valid sampling strategies could be developed in future programs, depending upon management planning objectives for the area. A secondary objective was to relate these data with parameters, such as topography, wind direction, vegetation types, animal behavior, that might help explain the pattern of dispersal. In 1972, 2625 circular sampling sites were surveyed along 30 transects radiating out 2.4 to 3.2 km from the B-C Cribs. Radioactive contaminated feces, urine, soil and vegetation were distributed in all directions from the cribs, but the area to the south and southwest was more densely and uniformly contaminated. Of the ultimate sampling units surveyed, 278 or 10.6% had activity in excess of 10,000 counts per minute (cpm) measured with a Geiger-Mueller counter. Of these 278 circular areas, 179 or 64% were found within 0.5 km of the cribs, 23.4% were between 0.5 and 1.0 km, and the remaining 12.2% were further than 1 km from the central point. Although most droppings with a count rate greater than 20,000 cpm were found within 400 meters of the crib, pellets registering in excess of 100,000 cpm were found up to 1.6 km from the cribs. The pellets appeared to be distributed into the prevailing wind directions and contrary to the immediate contours: the only correlation seemed to be with increased vegetation density to the south and southwest, vegetation that is prime jackrabbit habitat. In May-June, 1973, 48 additional transects were run: 7 were parallel to lines established in the B-C Crib Area during 1972; 18 radiated from an abandoned gun battery site 3.2 km east of the cribs; and 23 were run from power lines 5 km south to southwest of the cribs back towards the source of contamination. No

contaminated jackrabbit pellets were found at these distances, but one contaminated coyote scat was found near the gun battery site. During 1972 and 1973 field crews walked 106.7 km along 78 radii and recorded observations on 6671 ultimate sampling units of approximately 1.4 m^2."

Thus, it can be seen that this was an extensive survey with more than 6,600 individual spots being examined. The activity on the ground generally decreased with distance from the source, although one hot pellet (>100,000 cpm) was found a mile away. The pattern of activity seemed to correlate with the prevalence of dense sagebrush, preferred jackrabbit habitat. It is important to note that the authors concluded "It would appear that the active dunes south of the cribs acted as a natural barrier to displacement since we have found no contaminated hare pellets on the far side of the dunes." They also concluded that "Since we found contaminated pellets at least 2.4 km (1.5 miles) from the B-C Cribs, we must assume that there is a finite, albeit very low, probability that other pellets could be found at greater distances from the source." Thus, this survey reasonably delineated the extent of the contamination and concluded that there was a low probability of pellets further than 1.5 miles from the source and there was unlikely to be any pellets south of the dunes.

It was also reported that "Field parties surveyed predator habitat within 3000 ha and up to 20 km from the B-C Cribs. Only four sources of radioactive contamination was found: (1) Coyote feces was found near the abandoned gun battery site 3.2 km east of the B-C Cribs. (2) Several jackrabbit bone fragments were found near a Swainson's hawk nest 9.7 km southwest of the cribs. (3) Jackrabbit bone chips and contaminated dirt were found under a tree at an abandoned gun battery site 5.6 km south of the cribs. (4) Unidentified bone fragments were found under power line poles 5.6 km south to southwest of the cribs. Circumstantial evidence indicated that the tree and power line poles were feeding stations for predatory birds." Thus, one coyote scat and three sets of bone fragments from predatory birds were all that was found. Given the range of the coyotes and the birds, it is not certain that these were from the BC Area.

3.2.2 1973 Aerial Gamma Survey

On May 30-June 1, 1973, an aerial gamma survey was conducted over the BC Cribs Area (ARH-SA-226). Total manmade gamma radiation between 50 KeV and 3 MeV, and Cs-137 gamma radiation were measured and reported. See Figure 2-7 for a map showing the Cs-137 iso-exposure contours, which show the same general pattern of dispersal as the 50 KeV-3 MeV iso-exposure contours. The results show that the gamma-emitting radioactive material primarily is Cs-137 with some Co-60 and Am-241, as well as "a few other isotopes."

Several features of this map deserve some mention:

1. The hot spot between Trenches 216-B-29 and 216-B-53A is buried, aboveground transfer piping.

2. The hot spot between Trench 216-B-20 and the cribs is buried, aboveground transfer equipment that subsequently was found and removed in the early 1980s.

3. The elevated area immediately to the east of the southern-most trenches is an area that has been pointed out several times as being heavily contaminated.

4. The two hottest spots are at some distance from the trenches, just south of ARHCO Street. The contamination appears almost to radiate out from this spot; the reason for this is not understood.

5. The area of heaviest widespread contamination generally is to the south and southeast of the hot spots, toward the area of densest sagebrush.

6. Spotty detectable Cs-137 contamination extends into the dune area to the south, but is not found south of the dunes.

7. It needs to be kept in mind that Cs-137 activity as shown on this map is only 15 percent of the activity present at that time; 85 percent was Sr-90, which would not have been detectable by aerial survey (because Sr-90 and its daughter have only very low-intensity gamma and X-ray emissions).

ARH-SA-176, *Aerial Gamma Survey by Helicopter to Measure Surficial Contamination*, notes that the attenuation coefficient for Cs-137 gammas in soil is about 0.15, which results in a half-thickness of 7.5 cm of soil. That is, if the Cs-137 activity were covered by 3 in. of soil, it would appear to be half as concentrated as it actually is.

3.2.3 Brun's Assessment of Radionuclides and their Amounts

L. E. Bruns, in "Status of BC Crib Surface Contamination Development Work" (Bruns 1974a) combined the results of the aerial Cs-137 gamma survey and soil depth measurements of Cs-137 and Sr-90 to estimate the total activity dispersed in the controlled area at that time. His best estimate was 96 Ci with 14.5 Ci from Cs-137 and 81.5 Ci from Sr-90; he estimated the potential range of actual total activity to be between 40 and 140 Ci. Based on depth distribution studies, he estimated various levels in the soil (see Table 3-6, "Radionuclide Content of Trenches 216-B-53A, -53B, -54, and -58").

Table 3-6. Total Activity vs. Depth for BC Cribs Area in 1973 (All Activities in Curies).

Depth (cm)	Cs-137	% Cs-137 Total	Sr-90	% Sr-90 Total	Total	% Total
0 – 1.0	5.0	34	20.0	25	25.0	26
1.0 – 2.5	3.0	21	13.5	17	16.5	17
2.5 - 5.0	2.5	17	12.5	15	15.0	16
5.0 – 10.0	2.0	14	16.0	20	18.0	19
10.0 – 20.0	1.5	10	12.0	15	13.5	14
20.0 – 30.0	0.5	3	7.5	9	8.0	8
Totals	14.5	--	81.5	--	96	--

Source: Bruns, L. E., 1974a, "Status of BC Crib Surface Contamination Development Work," Letter from Atlantic Richfield Hanford Company to H. L. Maxfield, Atlantic Richfield Hanford Company, Richland, Washington, July 11.

Note that this Cs-137 penetration into soil is very different from the Cs-137 penetration found in arid soil from airborne deposition. In the case of airborne deposition, almost all (99 %) of the Cs-137 is found within the top 5 cm ("The Depth Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples" in *Radiochimica Acta* [Price 1991]) (see Figure 3-8, "Depth Distributions for Cesium-137, Strontium-90, and Plutonium-239/240 in Hanford Site 200 Area Soil," in Section 3.5.1). In addition, Sr-90 generally is confined to the top 15 cm in airborne deposition, while here it penetrates to at least 30 cm. Price's results are applicable to the area below the belt of sand dunes and are discussed further below.

Bruns (1974a) determined from soil samples, mostly taken from areas of higher activity, that the strontium-to-cesium ratios vary with depth (see Table 3-7, "Strontium/Cesium Ratios from High-Activity Areas in BC Cribs Area [1973]"). Thus, the fraction of the total activity that is strontium increased sharply with depth (as expected).

Table 3-7. Strontium/Cesium Ratios from High-Activity Areas in BC Cribs Area (1973).

Depth	Ratio Strontium/Cesium
0 – 5.0 cm	4.5
5.0 – 20.0 cm	8.0
20.0 – 30+ cm	15.0

Source: Bruns, L. E., 1974a, "Status of BC Crib Surface Contamination Development Work," Letter from Atlantic Richfield Hanford Company to H. L. Maxfield, Atlantic Richfield Hanford Company, Richland, Washington, July 11.

Bruns also investigated the activities of other radionuclides in high-activity soils with these results:

- Pu-239/240: <0.1-1.3 x 10^{-10} g/g soil
- Eu-155: 6.0 x 10^{-11} Ci/g (max)
- Co-60: 7.0 x 10^{-12} Ci/g (max)
- Am-241: 1.0 x 10^{-10} Ci/g (max).

Bruns also reported the presence of other radionuclides whose concentrations were not given but whose concentrations were apparently at levels that he considered small: Eu-154, U-238, U-235, Ru-103, Pu-238, Ru-106, Rh-106, Co-57, Sb-125, Ra-226, Cr-51, Sr-85, Eu-152, Cs-135, Ce-141, Th-228, K-40, and Ra-228.

Bruns reported that gamma exposure rates had been measured over the BC Area. The measured values varied between 100 and 1200 mR/yr. (The background was reported to be 60 to 80 mR/yr.) The majority of the high areas were between 300 and 700 mR/yr. He noticed a clear drop in exposure rates in areas near the firebreak roads from 300 to 700 mR/yr to 100 to 150 mR/yr. Bruns also reported, in "Dose Rate Studies in the BC-Cribs Controlled Area – May and June 1973" (Bruns 1974b) that the measurements were made with GE Reuter-Stokes, Inc., argon dosimeters (the term "argon dosimeter" was not further explained in the reference) and that the highest value found was 1640 mR/yr.

Concerning leaching, Bruns reported "actual soil analyses and a noticeable drop in surface activity from initial measurements show that both Strontium-90 and Cesium-137 are being leached downward with rainwater." Thus, both nuclides were being leached downward with time.

3.2.4 Maxfield's Conclusion on the Extent of Contamination

As mentioned above, H. L. Maxfield, in ARH-3088, discusses two zones, A and B, which were distinguished by the degree to which the contamination had been determined to be continuous. (The map for these zones is given in ARH-3088, Appendix K-5. These zones were drawn after extensive radiological characterization of the area, as reported in "Status of BC Crib Surface Contamination Development Work" [Bruns 1974a]).

Zone A is a 560-acre area where the soil contamination was determined to be essentially continuous over the entire area. This area had more than 2,000 radioactive fecal pellets per acre. This zone corresponds closely to the 0.59 to 0.88 $\mu Ci/m^2$ contours shown on the 1973 Cs-137 aerial survey (see Figure 2-7). Maxfield noted that this included the area with surface contamination between 1 to 10 $\mu Ci/m^2$.

Zone B comprises approximately 2,000 acres contained in a concentration of generally less than 1 $\mu Ci/m^2$. Within the perimeter of Zone B were 500 scattered acres believed to be essentially free of contamination. Zone B circumscribes most of the 0.12 to 0.18 $\mu Ci/m^2$ area shown on the 1973 Cs-137 aerial survey. See Figure 2-16 for a representation of Maxfield's Zones A and B.

3.2.5 Summary Discussion

The best representation of the areal extent of the contamination is given by the 1973 aerial survey. It was a careful survey done specifically to determine the extent of the contamination spread. It shows more resolution than subsequent airborne surveys. The best estimate of the spottiness or continuity of the contamination is Maxfield's Zones A and B, because they were established after extensive work in the early 1970s. As discussed below, further airborne surveys and other types of surveys indicate that the activity has not moved (substantially), but has leached into the soil.

3.3 SPREAD OF THE RADIOACTIVE MATERIAL AFTER THE INITIAL MEASUREMENTS

The characterization work done in the early 1970s and discussed above provided a reasonable initial understanding of the distribution of radionuclides within the area at that time. However, without remediation to fix or remove the radionuclides, it is necessary to consider the further dispersion of the radioactive material by natural forces. The three processes by which the material can be dispersed are animals, windblown plants, and windblown soil. Each of these is discussed below. Appendix C provides a summary of information on biota samples from the BC Area. The information was taken from the Near-Facility Monitoring Biotic Database.

3.3.1 Spread of the Radioactive Material by Animals

During the research into remediating the BC Cribs Area in the early 1970s, the possibility of biological transport from the BC Cribs Area was considered. W. H. Rickard, a Battelle Pacific Northwest Laboratory biologist, reported an assessment of the common animals occupying the BC Cribs Area and their ranges in "Biological Transport of Radionuclides from the B-C Crib Area" (Rickard 1974). These are as follows:

1. Animals with a restricted range of movement of ~0.1 mile: Townsend ground squirrel, pocket mouse, deer mouse, side-blotched lizard, darkling beetle.
2. Animals with a short range of movement. Animals resident to the BC Cribs Area that will probably not leave the Hanford Reservation and have a range of ~5 miles: black-tailed jackrabbit and gopher snake.
3. Animals with medium-range movement that can be expected to wander off the reservation after a visit to the BC Cribs Area: coyote and badger.
4. Animals with long-range migratory movement that leave the Hanford Reservation seasonally: grasshopper, Swainson's hawk, and meadowlark.

Thus, it certainly is possible for animals to transport radioactivity throughout the BC Controlled Area. However, this particular information gives no indication of the likelihood of such transportation.

One indication of the likelihood of radioactivity being transported by animals throughout the present BC Controlled Area comes from a study of such spread done in conjunction with the jackrabbit pellet distribution survey and reported in "Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation" in *Health Physics*. As mentioned above, this study reported that the sand dunes running east to west across the site appeared to act as a natural barrier to jackrabbits, thus limiting the dispersal in that direction. This study also reported this summary of the authors' efforts to find radioactive material that had been transported from the BC Controlled Area by animals.

> "Field parties surveyed predator habitat within 3000 ha and up to 20 km from the B-C Cribs. Only four sources of radioactive contamination were found: (1) Coyote feces was found near the abandoned gun battery site 3.2 km east of the B-C Cribs. (2) Several jackrabbit bone fragments were found near a Swainson's hawk nest 9.7 km southwest of the cribs. (3) Jackrabbit bone chips and contaminated dirt were found under a tree at an abandoned gun battery site 5.6 km south of the cribs. (4) Unidentified bone fragments were found under power line poles 5.6 km south to southwest of the cribs. Circumstantial evidence indicated that the tree and power line poles were feeding stations for predatory birds." (NOTE: Some unneeded detail was removed from this quoted section.)

Thus, one coyote scat and three sets of bone fragments from predatory birds were all that was found in a 3000-hectare area around the BC Cribs and Trenches Area and up to 20 km from the area. This indicates that the spread by predatory animals outside this area was by no means great. Given the range of the coyotes and the birds, it is not certain that these were from the BC Area.

The types of contamination resulting from animals that might be expected at some distance from the initial contamination area include bone fragments; feces or spots where activity leached into the ground from feces, which likely would have a surface area of about 1 ½ ft^2 and be 9 in. or more deep ("Cleanup of B-C Cribs Controlled Area" [Oberg 1973]); and urine spots, which likely would be 8 to 12 in. in diameter and 6 to 8 in. deep (see interviews with David Ellingson, David Phipps, and Keith Yates in Appendix A).

Additional information on animals occupying the BC Area is given in BNWL-1931, *Diets of Black-Tailed Hares on the Hanford Reservation*; BNWL-1943, *Grasshopper Populations Inhabiting the B-C Cribs and Redox Pond Sites, 200 Area Plateau, United States Energy Research and Development Administration's Hanford Reservation*; BNWL-2181, *Characterization of Small Mammal Populations Inhabiting the B-C Cribs Environs*; PNL-2253, *Ecology of the 200 Area Plateau Waste Management Environs: A Status Report*; and WHC-EP-0771, *Comparison of Radionuclide Levels in Soil, Sagebrush, Plant Litter, Cryptogams, and Small Mammals.*

3.3.2 Spread of the Radioactive Material by Windblown Plants

During the research into remediating the BC Cribs Area in the early 1970s, the possibility of biological transport from the BC Cribs Area was considered. W. H. Rickard, a Battelle Pacific Northwest Laboratory biologist, reported an assessment of the plants occupying the BC Cribs Area ("Biological Transport of Radionuclides from the B-C Crib Area" [Rickard 1974]). Rickard reported that only two of the plants in the BC Cribs Area ordinarily break off at the ground level and are transported for long distances by wind: Russian thistle (tumbleweed) and tumble mustard. With strong winds, it is possible for tumbling plants to move off the reservation. Both of these plants can extract Cs-137 and Sr-90 from soil and then transport it by tumbling.

A detailed discussion of the plant communities near the BC Cribs is given in BNWL-1916, *Characterization of Plant Communities Adjacent to the B-C Cribs Controlled Area and Redox Pond Area on the 200 Area Plateau*, which reported the following.

> "Russian thistle is the most troublesome plant as far as waste burial is concerned. It can develop an extensive root system and has the ability to accumulate radionuclides from soil more effectively than other kinds of plants. Whole plants tend to break off at the soil surface when mature and these can be transported several miles by wind. Although present in the sagebrush and cheatgrass dominated plant communities at the B-C and REDOX [reduction-oxidation] study sites, it is more plentiful on the disturbed soils of the waste burial grounds."

This information is consistent with the information received by the environmental radiation protection technicians who report contaminated tumbleweed, but who have found that tumble mustard is not generally contaminated (see interviews with David Ellingson, David Phipps, and Keith Yates in Appendix A). This information also is consistent with the descriptions of past tumbleweed problems at BC Cribs and Trenches, which report contaminated tumbleweed growing over the cribs and trenches themselves.

Thus, the (heavily) dominant contaminated, mobile plant in the BC Area is Russian thistle (tumbleweed), and it has grown largely over the actual cribs and trenches themselves. Therefore, the dispersion of contamination by plants can be considered to be, to a good approximation, totally by tumbleweed grown over the cribs and trenches themselves.

An obvious factor that would affect the potential dispersion of tumbleweeds from the BC Cribs and Trenches Area is the presence of these weeds on the site. Radioactive tumbleweed was common on the cribs and trenches site from the beginning of the site until the stabilization in 1982, a period of, say, 25 years. Tumbleweeds have been much less frequent since that time. Another obvious factor is the wind direction. The prevalent wind is from the northwest and would blow tumbleweed toward the BC Controlled Area; however, the strong winds are from the southwest (parallel to the band of dunes) and would blow tumbleweed largely away from the BC Controlled Area ("Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation" in *Health Physics*). Thus, because tumbleweeds appear to move primarily during periods of high wind, the likely movement of tumbleweed from the BC Cribs and Trenches would be away from the BC Controlled Area. A third obvious factor influencing the movement of tumbleweed is the presence of barriers to their movement, such as roads, fences, or dense plants. Tumbleweed originating on the trenches would have to pass through at least a mile of well-established sagebrush to reach the BC Controlled Area outside of the firebreaks. The firebreaks have been effective and this stand of sagebrush has not burned since the firebreaks were built in 1973. From the photographs of the area taken before 1973 showing many large sagebrush, it appears that the area had not burned for some years before 1973. In addition, BNWL-1794 mentioned the existence of a heavy growth of sagebrush to the south and southeast of the BC Cribs and Trenches Area; this also indicates that the area had not burned for some years before 1973.

Thus, although it certainly cannot be said with certainty that no such incident took place, it seems unlikely that large numbers of tumbleweed, under normal wind conditions, would have made it across the sagebrush area within the firebreaks to contaminate the remainder of the BC Controlled Area. They likely would have been trapped within the firebreak area. Nevertheless, some tumbleweed probably escaped from the firebreak area and contaminated the area to the east. However, David Ellingson noted (see interviews with David Ellingson, David Phipps, and Keith Yates in Appendix A) that in 2002 there was an extensive survey of tumbleweed at the Central Landfill, at the edge of the BC Controlled Area, and no contaminated tumbleweed was found.

As a point of interest, according to HW-18034, *The Absorption and Translocation of Several Fission Elements by Russian Thistles*, the contamination of Russian thistle had been known at the Hanford Site since December 1948, at the latest.

Material from contaminated tumbleweed that might be found at a distance from the BC Cribs and Trenches Area could be as large as an entire tumbleweed or a tumbleweed branch, or it could be as small as a tiny fragment or seed. Old contaminated plants could have decomposed and the activity leached into the soil in a small area. HW-18034 noted that the Sr-Y-90 concentration in tumbleweed growing on heavily contaminated soil was about 90 times the Cs-137 concentration. Also, BNWL-B-148, *A Critical Review of Biological Accumulation, Discrimination and Uptake of Radionuclides Important to Waste Management Practices 1943-1971*, noted that, in general, laboratory and field studies have established that plants uptake and translocate to shoot tissue strontium far more readily than they do cesium. Thus, the ratio of Sr-Y-90 to Cs-137 in tumbleweed from the BC Cribs and Trenches likely is to be very large, maybe as much as 100. Therefore, heavily contaminated tumbleweed fragments may not be readily detectable by gamma detectors.

3.3.3 Spread of the Radioactive Material by Windblown Soil

In 1973, G. A. Sehmel measured airborne concentrations of Cs-137 and Sr-90 in the BC Area during four representative time periods varying from late spring to early winter (see "Particle Resuspension at B-C Area" [Sehmel 1974]). All measured concentrations of Cs-137 and Sr-90 were on the order of 10^{-14} to 10^{-15} µCi/cm^3, which are orders of magnitude less than the MPCs in air for continuous exposure in force at the time: 2×10^{-8} µCi/cm^3 for Cs-137 and 1×10^{-10} µCi/cm^3 for Sr-90. These values were not significantly different from the general onsite environmental surveillance data available at the time (see ARH-3088). Thus, significant contamination likely would not have been spread by particle resuspension in the BC Area.

Sehmel's work is further described in BNWL-2081.

3.3.4 Spread of Radioactive Material by Range Fire

ARH-3088 concluded that the major risk of spread of contamination was from high winds after a range fire. For this reason, the firebreaks, which enclose almost all of the contaminated area, were constructed in 1973. These firebreaks have been successful and none of this area has burned since then, save one small corner. Furthermore, an examination of the airborne photographs taken at various times shows no evidence of a range fire in the BC Area between the time the cribs and trenches were built and the time the firebreaks were built. Thus, there has been no spread of radioactive material from the heavily contaminated area by range fire.

There are some areas of contamination that are not within the firebreaks and that have burned in recent range fires (see the aerial survey maps). However, only a small fraction of the contamination in the soil would actually be available for dispersion. BNWL-B-337 showed that of the Cs-137 activity in the top 1 cm of surface material, 90 percent is held in the soil and about 10 percent is in organic material that might burn. BNWL-B-303, *Potential Airborne Release of Surface Contamination During a Range Fire in the B-C Controlled Area*, showed by experimental measurement that 8 percent of the ash from burned detritus was resuspended by winds of 20 mi/h; 0.6 percent was resuspended by winds of 2.5 mi/h. Thus, a fraction of the burned organic material would be resuspended by wind after a fire.

Given that relatively small areas of low concentrations of radioactivity were outside the firebreaks and only 10 percent of the activity would be available to burn and of this only a small fraction would likely to be resuspended, it appears unlikely that much activity could be dispersed by this route. Although a small amount would be resuspended, it does not appear that this would be a significant source outside the immediate area of contamination.

The conclusion that only very small amounts of radioactivity would be moved during a range fire is supported by data taken during the last large range fire in 2000. None of the air samples that were taken by the Hanford Site Near-Facility Monitoring Program during the fire and subsequently analyzed by gamma spectroscopy analyses showed any evidence of the nuclides chosen for analysis: Be-7, Cs-137, and Am-241 (Be-7 is primarily a naturally occurring radionuclide). In all cases, the gamma results were less than the minimum detectable concentration. This is indicative of the very small amount of radioactivity airborne during a major range fire on the site. These data are found at www.hanford.gov/envmon/index.html.

3.3.5 Summary Discussion

The information presented in this section indicates that there are only small amounts of activity outside the immediate area of its origin (after the initial deposition) by any of the mechanisms considered here: animals, windblown plants, windblown soil, and a range fire. The most likely mechanisms would have been spread by animals and tumbleweeds. There likely is tumbleweed contamination to the east of Dupont Avenue.

Animal contamination would be bones, feces, urine spots a few inches in diameter by a few inches deep, or spots where feces has leached into the ground, also a few inches in diameter and a few inches deep. Plant contamination could be an entire tumbleweed, branches of a tumbleweed down to tiny fragments, and seeds. Plant material also could have decomposed and leached into the soil.

3.4 MONITORING OF THE SPREAD OF RADIOACTIVE MATERIAL

During the period since the original surveys, activities have been carried out to monitor the spread of contamination. These include three subsequent aerial surveys, the routine surveying of established plots, and road surveys.

3.4.1 Subsequent Aerial Surveys

Since the initial aerial survey in 1973 (see Figure 2-7), there have been three additional airborne surveys: 1978 (see Figure 2-8), 1988 (see Figure 2-21), and 1996 (see Figure 2-22). The 1996 survey data are preliminary, because the survey data never were completely processed and only preliminary data are available.

3.4.1.1 1978 Aerial Survey

This Cs-137 iso-exposure survey gives no indication that the radioactive material is spreading in any substantial way. The conversion scales are much broader than those given in the 1973 survey, so comparisons are only general. The most contaminated spot in the 1973 survey shows a Cs-137 exposure rate of about 90 μR/h; the same spot in the 1978 survey shows an average Cs-137 exposure rate of about 40 μR/h. This cannot be accounted for by physical decay and probably is due to additional leaching into the ground and different survey equipment and techniques used in the airborne survey. Nevertheless, it shows the same general contamination pattern and, as mentioned above, gives no indication that the contamination is spreading. See Figure 2-8. This work is documented in EGG-1183-1828.

3.4.1.2 1988 Aerial Survey

The 1988 aerial survey is documented in EGG-10617-1062 and the manmade gross count contours are shown in Figure 2-21. Note that this survey recorded all photons thought to be manmade, not just Cs-137. The contour map makes this note about the use of manmade gross counts:

> "The results are displayed as relative levels of radionuclide activity. It is nearly impossible to convert the relative levels of activity to a meaningful exposure rate because of the complex distribution of the nuclides."

Thus, it is even more difficult to directly compare the results of this aerial survey to the other three than it is to inter-compare them (they are all based on Cs-137). Nevertheless, it does show the same general distribution of activity as shown in all the others and, therefore, gives no indication of any spread of activity.

Concerning the appropriate use of aerial radiation surveys, EGG-10617-1062 notes "Aerial systems integrate radiation levels over an area whose diameter may be 10 times the height of the platform above the ground. This is a function of the gamma ray energies, their origin within the soil matrix, and the response characteristics of the detector package. For activity fairly uniformly distributed over large areas, which is typical of natural background radiation, the agreement between ground-based readings and those inferred from aerial data is generally quite good. Because of the large-area integration of the airborne system, localized anomalies will appear to be spread over a larger area with lower activity than actually exists on the ground. Therefore, for localized anomalies, ground-based measurements will not agree very well with aerial results. The aerial data, therefore, simply serves to identify the existence of such anomalies. Ground-based surveys are required for more accurate definition of the spatial extent and intensity of the anomaly." Thus, airborne surveys in general serve only as a guide to the extent and intensity of radiation on the ground.

3.4.1.3 1996 Aerial Survey

The data used from the 1996 aerial survey are preliminary, because the DOE never obtained the final data. The entire documentation that is available consists of a single contour map marked "preliminary;" no written report from those doing the survey has been found. The information was included because it is a reliable survey, and it shows the same distribution pattern that all the previous aerial surveys have shown. Thus, it gives no indication of any substantial spread of the radioactive material. See Figure 2-22. The units ($\mu Ci/m^2$ Cs-137 surface concentration) for the survey were not given on the preliminary contour map, but were given in BHI-01202.

3.4.1.4 Summary Discussion

The four aerial surveys, although not directly comparable in their detailed results, do agree on the basic areal distribution of the contamination: the highest level of contamination is in the same area on all surveys, just south of the trenches; an arm of the contaminated area extends toward the southeast; an arm of the contamination extends toward the southwest; a contaminated area exists west of Isochem Avenue and along Isochem Avenue; and contamination exists south of Rockwell Street and extends into the dunes that run generally east to west. The four surveys, taken as a whole, support the important conclusion that the contaminated area has not moved in any substantial way; the later surveys show the same areal pattern as the first with no new areas of contamination.

It has to be emphasized that the detailed results—exposure rates and contamination concentrations—of these surveys are not comparable. Several variables would cause different results from those expected from physical decay. First, the radionuclides have leached further into the ground in the last 30 years. The half-value thickness for soil for Cs-137 is 7.5 cm; therefore, the detected result would be reduced by 50 percent for each 7.5 cm that the Cs-137 has leached into the soil. Second, differences in detector speed, altitude, type, and software likely would result in differences in prediction even for the same area at the same time. Thus, the results cannot be reliably compared in detail. As discussed, one of their values is to guide the more accurate ground surveys.

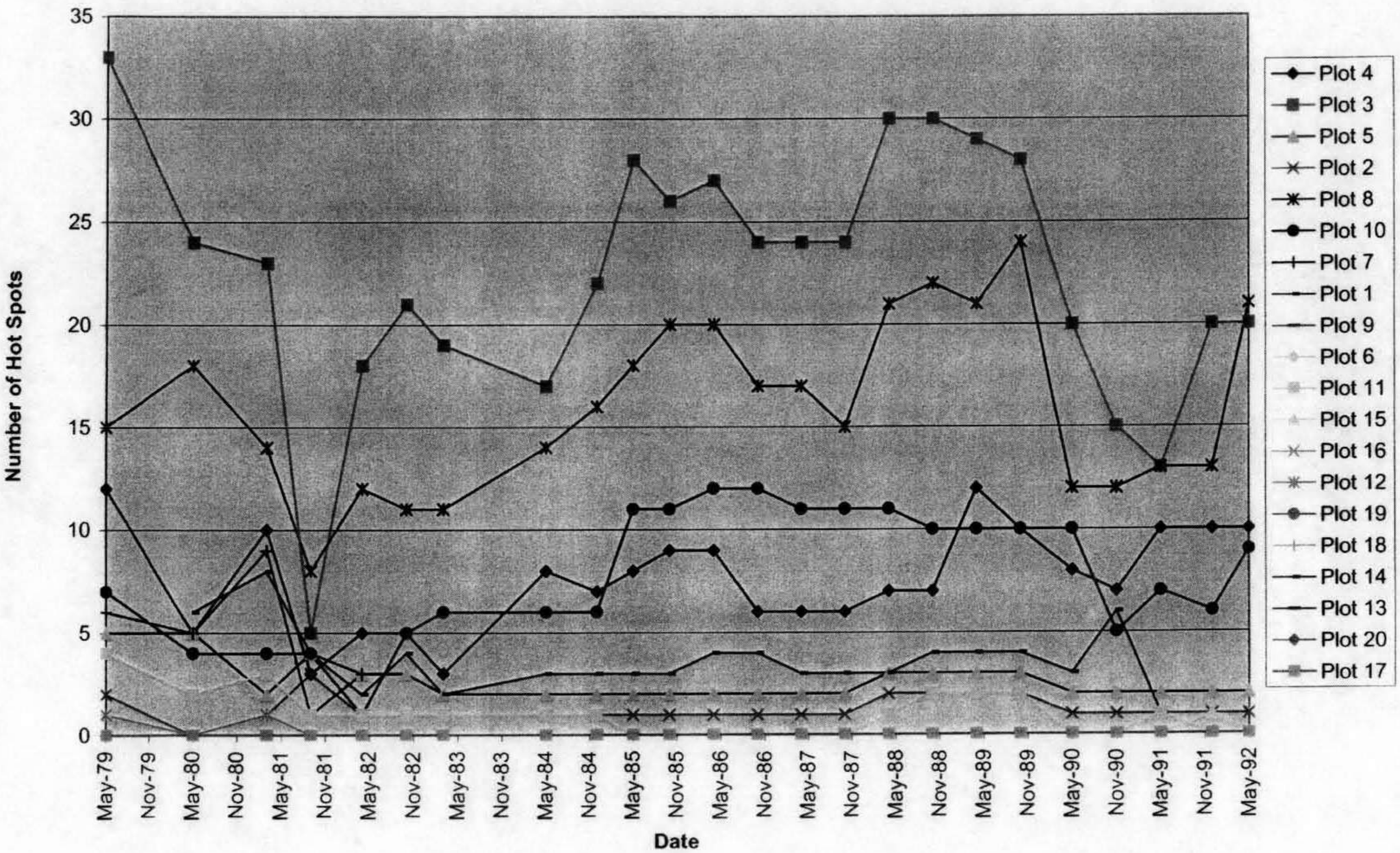
It also must be constantly borne in mind—and it is easy to overlook—that the survey results are depicting approximately 15 percent of the total activity, the Cs-137. The Sr-90 is believed to account for almost all of the remaining 85 percent. It seems reasonable that the Cs-137 and the Sr-90 generally are comingled, so that in all locations where there is some strontium, there also would be some cesium. There is no guarantee of this, either due to physical separation by chemical process or biological separation by the animal. In fact, there is evidence of considerable contamination (corner of Rockwell Street and Dupont Avenue) in an area that does not show up as contaminated on any of the four aerial surveys.

3.4.2 Survey Plots

Survey plots, small areas in various locations that were routinely surveyed, were established in the late 1970s as a means to monitor the movement of contamination within and around the contaminated area within the firebreak roads. The use of the plots was discontinued in the early 1990s. During this period, the plots were surveyed for contamination twice a year. The survey plot locations are shown on Figures 2-7 and 2-16.

The number of hotspots found on the survey plots at various times is shown on Figure 3-1, "Number of Hotspots per Survey Plot vs. Time." Note that the most frequently contaminated plots—3, 8, 10, and 4—are all in areas of high contamination as indicated on the aerial survey. For instance, plot 3, the one with the most frequent contamination, is very near the area of maximum ground contamination. The other plots showing general elevation—1, 5, 2, and 11—are also on areas of higher, but less, contamination. Perimeter plots, such as 20, 19, 18, 17, 14, and 13, show few, if any, hot spots over time. Many of the zero values do not show on the figure, because they are overwritten by other zero values. Thus, the frequency of hot spots correlates well with the degree of contamination of the ground upon which the plot is located. Because the perimeter plots show few, if any, hot spots, there is no evidence that the contamination is moving to any degree outside the areas of highly contaminated soil. The variation in the number of hot spots on plots in highly contaminated areas appears to be consistent with local movement of contamination within the highly contaminated area.

Figure 3-1. Number of Hotspots per Survey Plot vs. Time.



However, again, these data, taken as a whole, give no evidence of widescale movement of contamination by wind, plants, or animals.

The frequency of hot spots as a function of the distance from the area of highest ground contamination was reviewed, and this information is shown in Figure 3-2, "Average Number of Hotspots vs. Distance from Area of Highest Ground Contamination." This figure shows that none of the survey plots beyond about 1500 m from the area of highest ground contamination show any significant contamination. This may be partly due to the specific locations of the plots, but it is consistent with the known general extent of the contamination (it is not greater than the areas of known ground contamination).

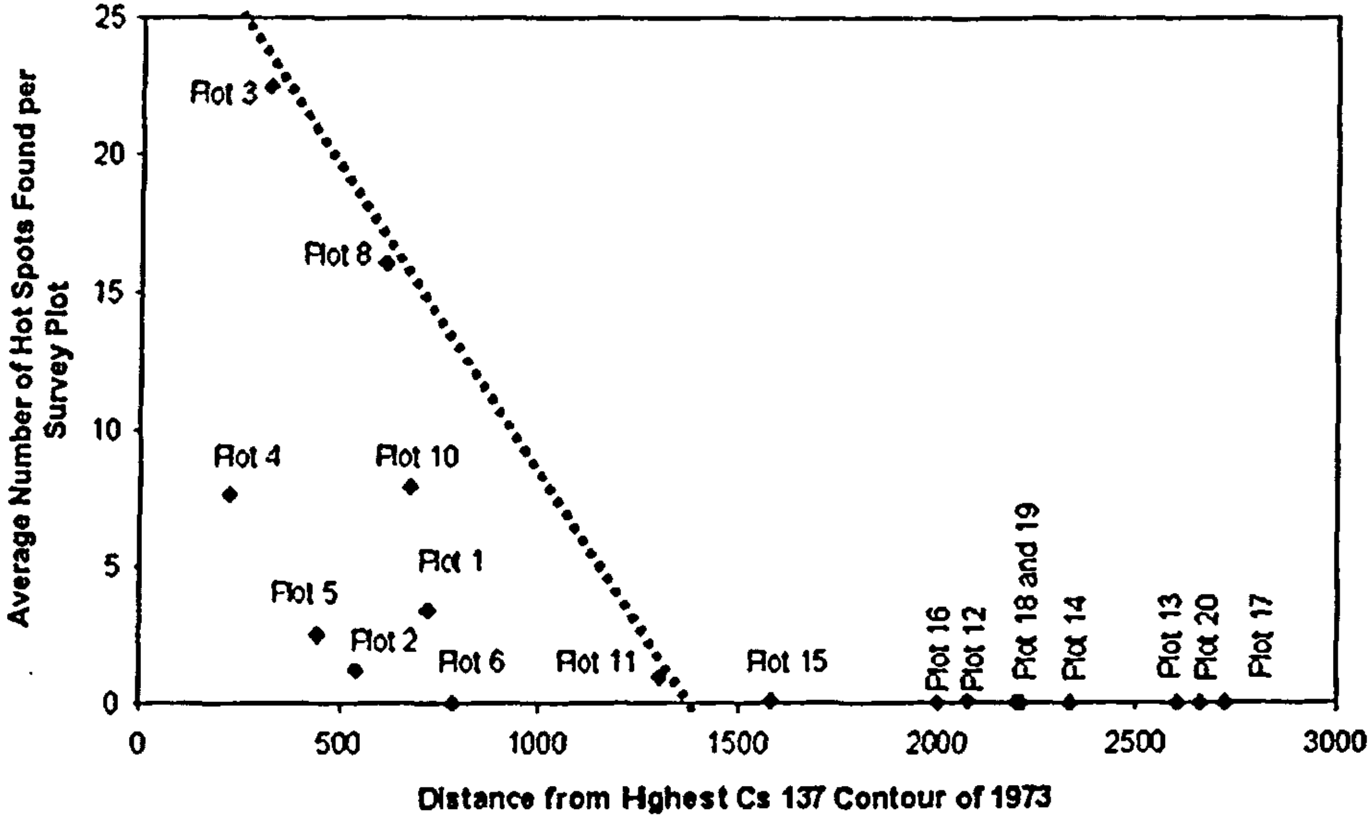
3.4.3 Perimeter and Firebreak Road Surveys

3.4.3.1 Perimeter Road Surveys

The surveys of the roads that circumnavigate the BC Area are important as indications of the movement of radioactive material. The surveys are done with large gamma-detecting instruments mounted on a tractor, referred to as the MSCM-II. There are two of the tractor-mounted systems. These detectors are sensitive to gamma-emitting contamination but have low sensitivity to beta particles. Tumbleweed with significant levels of Sr-90 but small levels of Cs-137 (tumbleweed is biologically selective for strontium over cesium) may not be detected with this instrument (unless, of course, the quantity of cesium present is sufficient to meet the detection limit). *Minimum Detectable Activity of the Mobile Surface Contamination Monitor MSCM-II* (Ford 1995) estimated the minimum detectable activities for one of these tractor-mounted systems. Based on Ford's data and for the usual survey conditions of 2 mi/h and 6-in. detector-to-source distance, the minimum detection activity (MDA) for a point source of Cs-137 is about 365,000 dpm, and the MDA for a point source of Sr-90 is about 537,000 dpm. This report never was completed and was left in draft form. There are no approved MDA determinations for these instruments.

Records have been found for perimeter surveys done at these times: (1) March 5-11, 2003; (2) December 27, 2001; (3) July 17, 2001; (4) May 3, 2000; (5) December 30, 1999; (6) April 6-12, 1999; and (7) October 9, 1997. Electronic data files have been found for the March 5-11, 2003, survey only. The others are available only as portable document format (PDF) files or black and white photocopies of colored PDF files and some of these are difficult to read or reproduce due to the size of the graphics. Only the most recent two are capable of being legibly reproduced, and they are given in Figures 3-3, "BC Area Radiation Area Remedial Action Perimeter Survey Data, 2003," and 3-4, "BC Area Perimeter Survey, December 27, 2001."

Figure 3-2. Average Number of Hotspots vs. Distance from Area of Highest Ground Contamination.



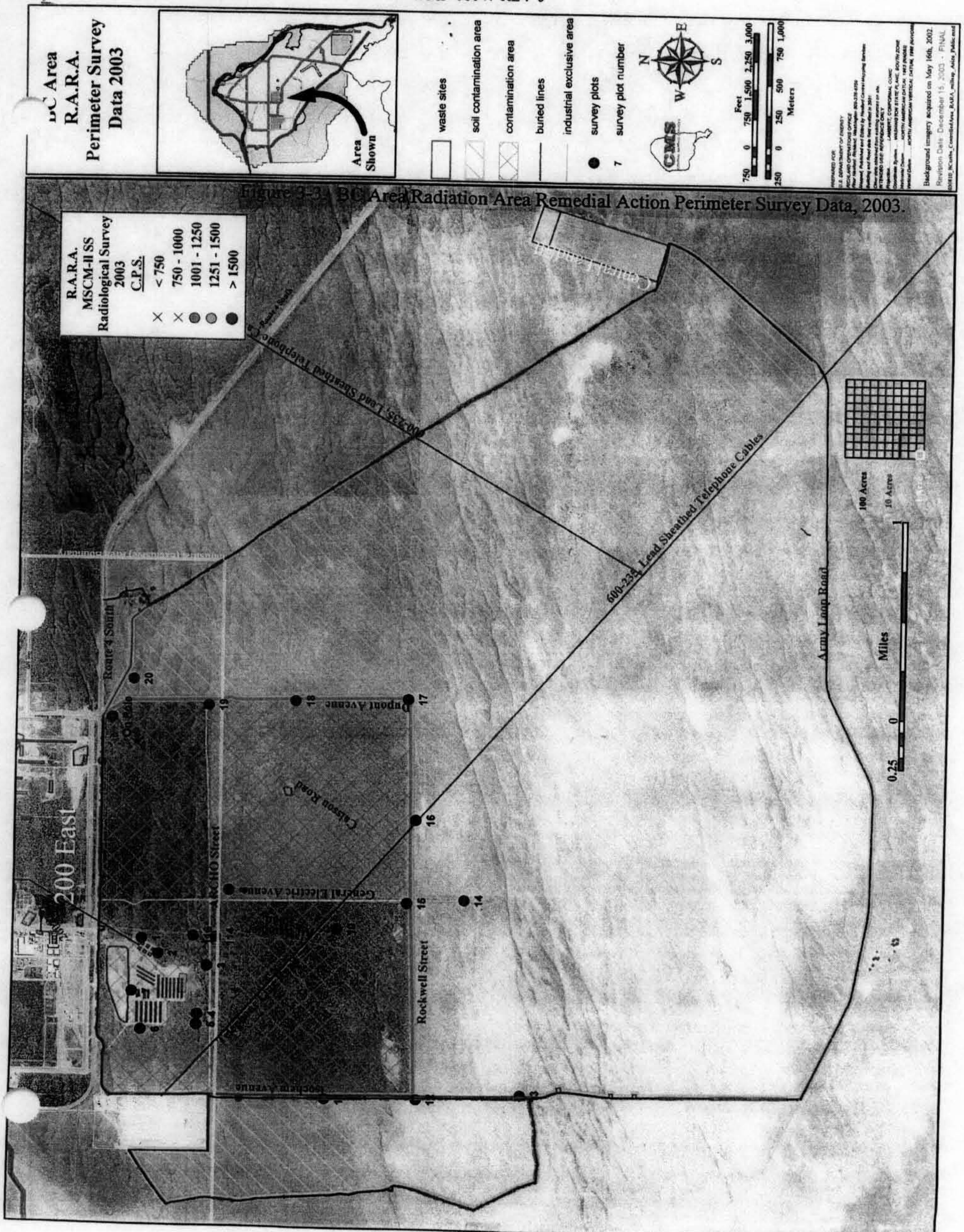
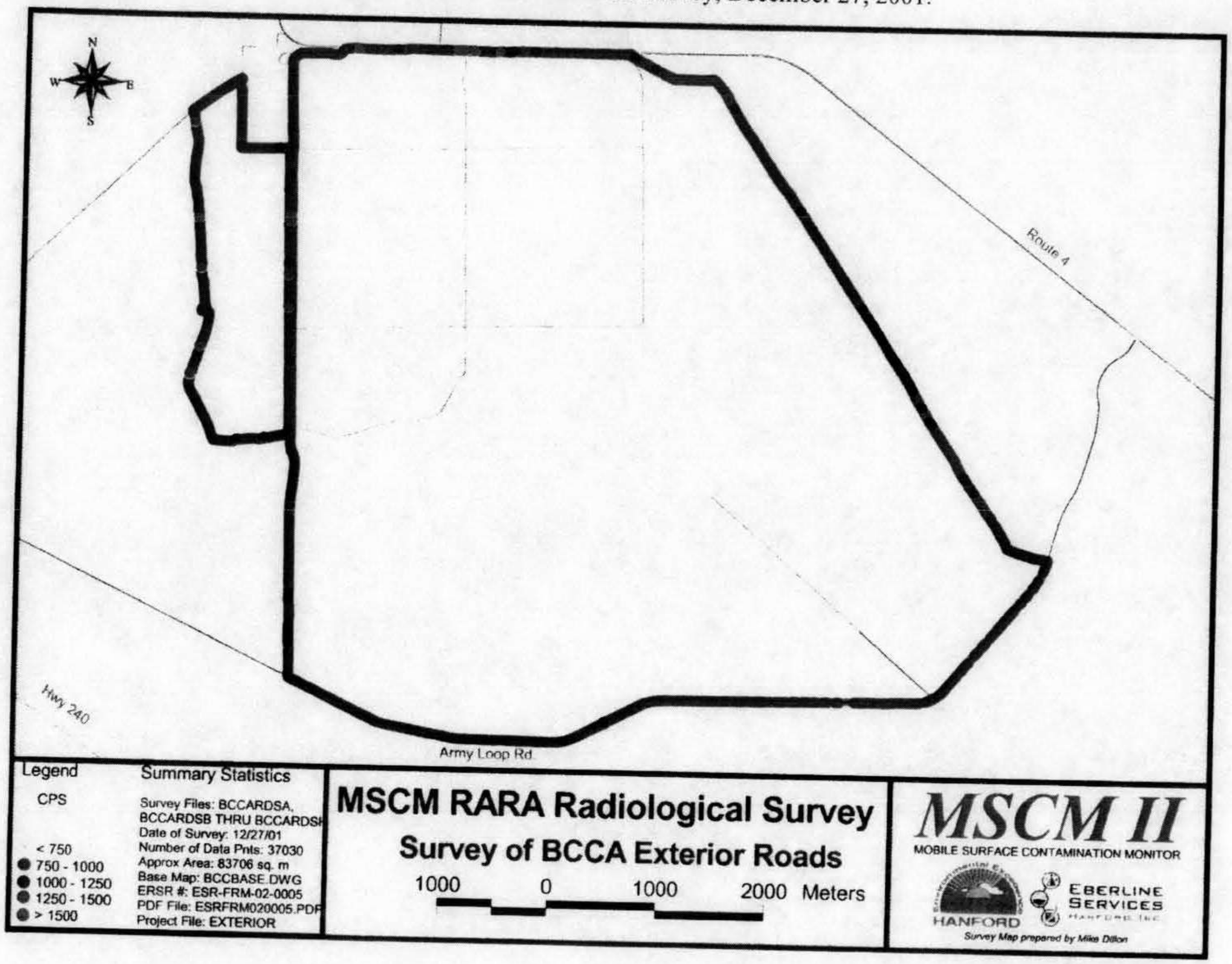


Figure 3-3. BC Area Radiation Area Remedial Action Perimeter Survey Data, 2003.

Figure 3-4. BC Area Perimeter Survey, December 27, 2001.



Neither the March 2003 survey nor the December 2001 survey detected any readings that were considered to indicate contamination at a level to require posting. However, both surveys showed elevated readings (below the trigger level of 1500 counts per [cps]) at three locations: (1) to the southeast in the dunes; (2) to the southwest at the intersection of the extension of Isochem Avenue and Army Loop Road; and (3) in the area to the west of the main BC Area and to the south and southwest of the U.S. Ecology site. The area to the west is known to be contaminated, and the surveys suggest the contamination may be further west than previously considered.

3.4.3.2 Firebreak Road Surveys

A number of surveys were performed between 1988 and 2002 of the firebreak roads and occasionally Telephone Line Road and Caisson Road. Occasionally, as would be expected from the degree of ground contamination in this area, spots of removable activity were found on these roads. Review of the data was difficult because some of the available information was black and white copies of poorly plotted, colored PDF files. However, from what could be made of it, no unusual patterns were noticed.

Copies of the following surveys (giving survey number and date) were reviewed:
(1) ESR-FRM-02-0016, 01-08-02; (2) ESR-TS-00-0363, 9-22-00; (3) EST-TS-00-0215, 5-04-00; (4) ESR-TS-99-0380, 12-29-99; (5) ESR-TS-99-0226, 8-11-99; (6) 96-TS-129, 6-6-96; (7) TS-0436, 12-19-95; (8) RARA 0301, 6-9-95; (9) 146342, 5-3-94; (10) 146339, 5-2-94; (11) N-148410, 4-13-93; (12) 72888, 4-7-92; (13) 006473, 10/21/91; (14) 006115; 9/20/91; (15) 905032, 6-7-90; and (16) 12097, 10-12-88.

3.4.4 1999 Sodium Iodide Transect Survey

In March 1999, as part of an effort to remove the radiological posting in the BC Area, BHI had a transect survey performed using sodium iodide (gamma) detectors. This survey was modeled after the 1972 jackrabbit pellet survey, which is shown in Figure 2-14 and discussed in Section 3.2.1. The original data files (giving detector count rate vs. Global Positioning System location) have not been found; however, a processed form of the data that categorizes the count rates by group was obtained. This information is shown in Figure 2-25. This survey information supports previous indications on the extent of the contaminated area and the area of greatest contamination. The sodium iodide detector would not see contamination that largely is Sr-90.

3.4.5 Other Surveys

In addition to the routine surveys discussed in this section, there are some occasional surveys that shed some light on the potential spread of contamination.

3.4.5.1 Surveys South of Rockwell Street and East of Dupont Avenue in Mid-1980s

As discussed in Section 2.7, the "Semiannual Radiological Survey Report for the Second Half of Fiscal Year 1984" (Wheeler 1984) mentioned surveys done in the dunes to the south of Rockwell Street and in the area to the east of Dupont Avenue, between Dupont Avenue and the present eastern boundary of the BC Controlled Area. As shown in Figure 17 of the referenced report, the road monitor was used to survey a path in the dunes running generally east and west and about 2 km long; the path was about a kilometer south of Rockwell Street and east of General Electric Avenue. The map noted that contamination was found throughout the path of the survey. The map also shows a road monitor survey from about the intersection of Dupont Avenue and Rockwell Street east for about a kilometer ending in an area chosen for detailed survey. The figure indicated that the road monitor found spotty contamination throughout the path and that in the area chosen for detailed survey, spotty contamination to 40,000 cpm was found. This is further indication of contamination spread into the dunes and into the area between Dupont Avenue and the present eastern boundary of the BC Controlled Area.

3.4.5.2 Surveys in Late 1990s Associated with the Expansion of the BC Controlled Area

A number of surveys associated with the expansion of the BC Controlled Area in the late 1990s (see Section 2.8.1) shed some light on the potential spread of contamination. On November 18, 1996, a tractor survey was done south of Army Loop Road from the Central Landfill to near the Rattlesnake Gate. This survey found only one spot of contamination. See Figure 3-5, "November 18, 1996, Tractor Survey South of Army Loop Road" and the interview notes with Barry Headley (Appendix A). A survey report labeled as "BC Control Area Survey, All Data Thru February 04, 1997" shows a large number of contaminated spots found in the area south of U.S. Ecology and west of Isochem Avenue (see Figure 3-6, "February 4, 1997, BC Controlled Area Composite Survey Results"). Many of these spots, found with a Geiger-Mueller counter, were recorded as being in the range of 10,000 to 100,000 dpm, and some were recorded as being greater than 500,000 dpm. Some of the more detailed survey results out of which this composite was formed (detailed surveys not reproduced in this report) show contact readings to 12 mrad/h. This is additional evidence that this area is widely contaminated.

An undated and unsigned report entitled *BC Controlled Area, Wildlife Migration Pathway, MRDS Radiological Surveys, Thermo Hanford Inc. Technical Report* records a survey conducted along a path south of Army Loop Road from the intersection of Isochem Avenue and Army Loop Road to near the Rattlesnake Gate. The survey was conducted from January 26 to February 18, 1998, and done with a beta-detector with the Global Positioning System locations being automatically recorded. The survey was motivated by the belief that contaminated animals from the BC Cribs and Trenches may have moved in this direction toward the water source at Rattlesnake Springs. A total of 51,690 survey points were logged along a survey route of about 4400 m. No reading considered statistically greater than background was reported. Thus, no evidence of large numbers of contaminated animals crossing this path was found. The survey map is shown in Figure 3-7, "1998 Survey of Suspected Animal Migration Path."

3.4.6 Summary Discussion

Collectively, the information presented in this section supports a number of important conclusions. First and most important, the information supports the conclusion that the bulk of the contamination is fixed in place in the soil and is not moving in any substantial way. The information is consistent with small, local movements of activity. The information shows that there is widespread contamination throughout the BC Area north of the dunes and that there is

Figure 3-5. November 18, 1996, Tractor Survey South of Army Loop Road.

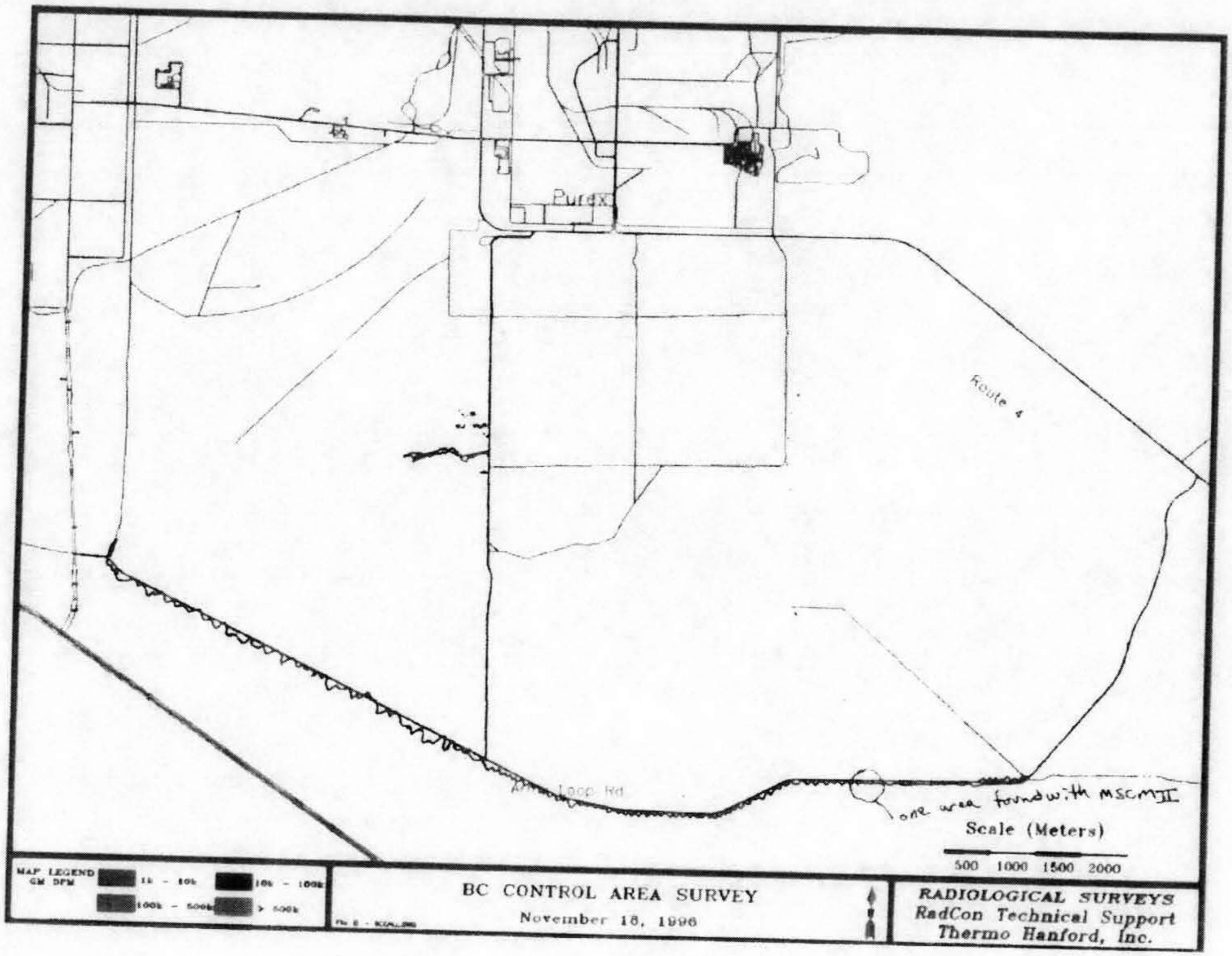


Figure 3-6. February 4, 1997, BC Controlled Area Composite Survey Results.

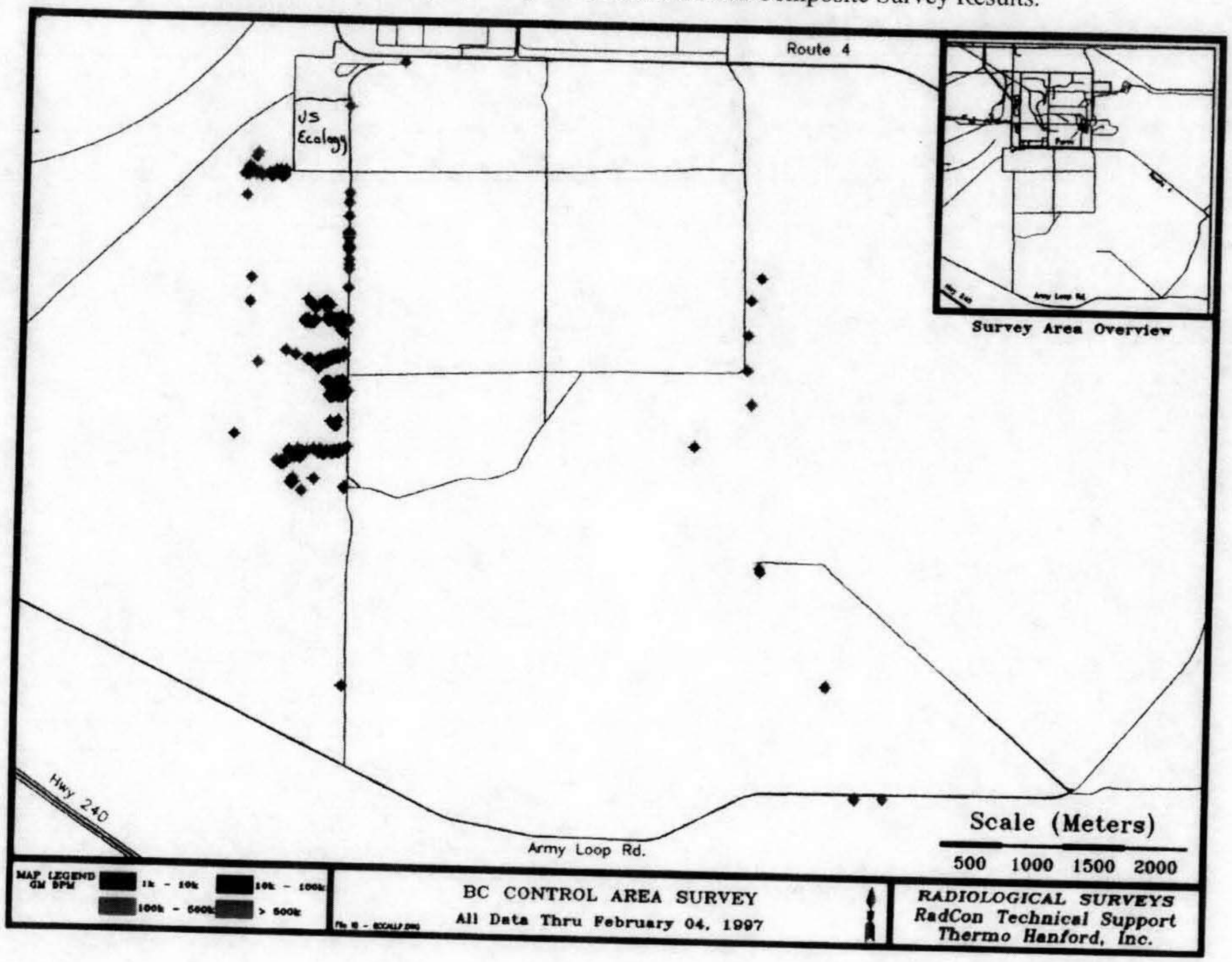
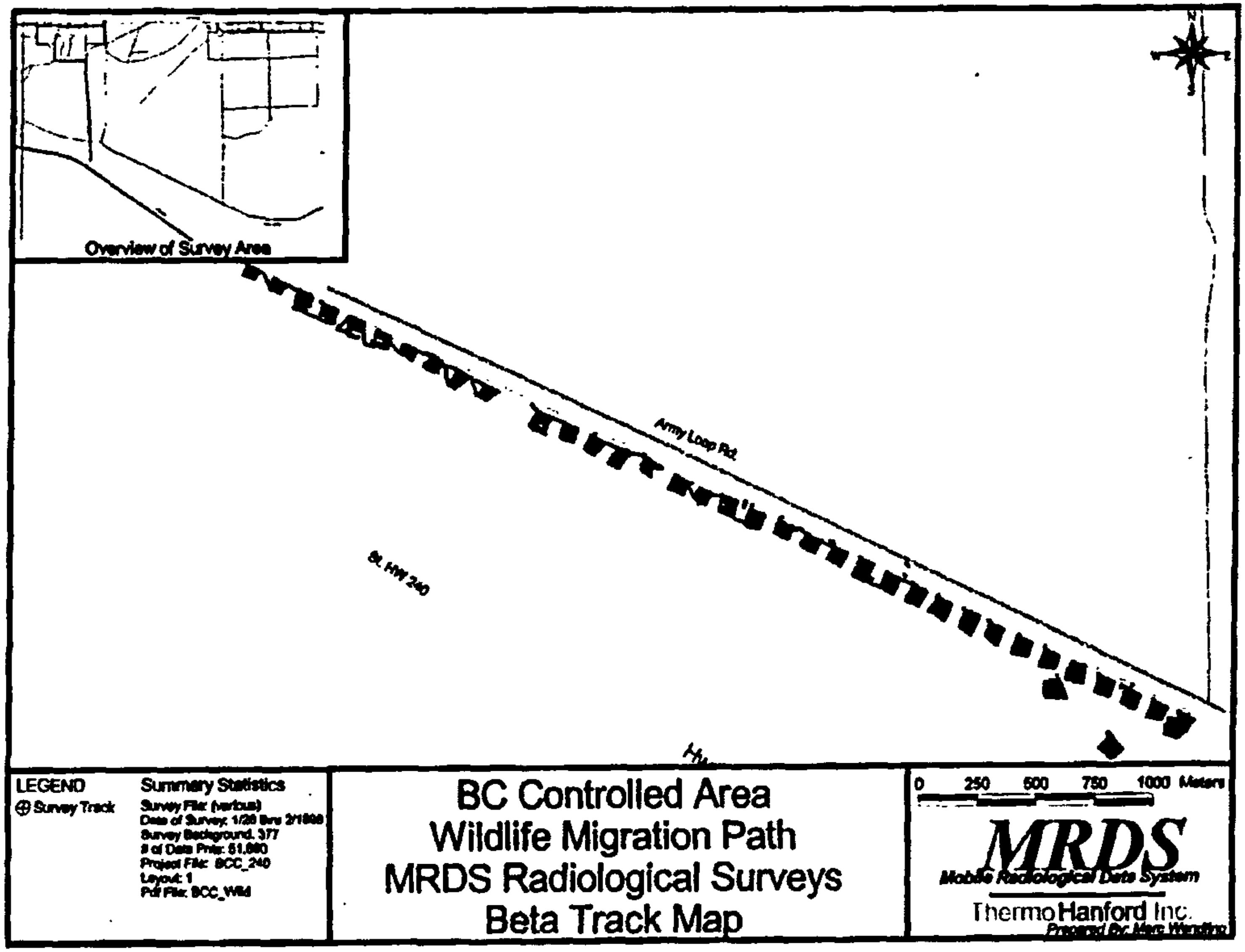


Figure 3-7. 1998 Survey of Suspected Animal Migration Path.



some contamination in the dunes. The information in this section provides only minor evidence of contamination south of the dunes (although there undoubtedly is some).

3.5 SOIL DEPTH DISTRIBUTION PROFILES FOR RADIONUCLIDES

The depth distribution of radionuclides in soil is important for two reasons: (1) it affects the dose calculations and, therefore, the allowable levels of activity in the soil; and (2) it might affect the amount of soil that would have to be removed to clean the surface of the land. For purposes of soil radionuclide distributions, the BC Controlled Area can be divided into two parts: (1) areas without animal waste (urine and feces) contamination, and (2) areas with animal waste contamination. The areas unaffected by animal contamination are contaminated by global fallout and airborne deposition from the 200 Areas and have soil distributions characteristic of such areas. On the other hand, the soil profiles for areas affected by animals are different, because the radionuclides from urine and feces penetrate the soil to greater depths.

3.5.1 Areas without Animal Waste Contamination

"The Depth Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples" in *Radiochimica Acta* (Price 1991) has examined the depth distributions for Sr-90, Cs-137, and Pu-239/240 in the top 30 cm of soil on the Hanford Site 200 Area Plateau and at a location off-site and upwind of the Hanford Site. The study showed that for the samples on the 200 Area Plateau the top 5 cm (2 in.) of soil contained 99 percent of the Cs-137, 96 percent of the Pu-239/240, and about 50 percent of the Sr-90. The Sr-90 is shown to be the most mobile, penetrating to a depth of about 18 cm. The graphs from Price's article that show the depth distributions for Cs-137, Sr-90, and Pu-239/240 in soil in the 200 Area are shown in Figure 3-8.

Additional discussions of this work are given in PNL-SA-16034, *The Distribution of Strontium-90 and Cesium-137 in Soil Profile Samples From the Hanford Site and Environs* and PNL-SA-16944, *The Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples.* A discussion of plutonium in surface soil at the Hanford Site is given in LA-4756, "Plutonium in Surface Soil in the Hanford Plant Environs" in *Proceedings of Environmental Plutonium Symposium.*

3.5.2 Areas with Animal Waste Contamination

There is both measurement and anecdotal evidence that Cs-137 and Sr-90 (and probably other nuclides) deposited in the soil in urine and feces penetrate deeper into the soil than that deposited by global fallout and 200 Area airborne deposition.

3.5.2.1 Measurement Evidence

The primary measurement evidence of the depth distribution profile in areas with animal waste contamination comes from L. E. Bruns ("Status of BC Crib Surface Contamination Development Work" [Bruns 1974a]). In his report, Bruns provides two sets of information leading to depth distributions and they do not agree well. The first one is a chart of percent activity versus depth (see Table 3-8, "Bruns' Report on Percent Activity vs. Depth in the Soil").

Figure 3-8. Depth Distributions for Cesium-137, Strontium-90, and Plutonium-239/240 in Hanford Site 200 Area Soil.
(from "The Depth Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples," *Radiochimica Acta* [Price 1991]).

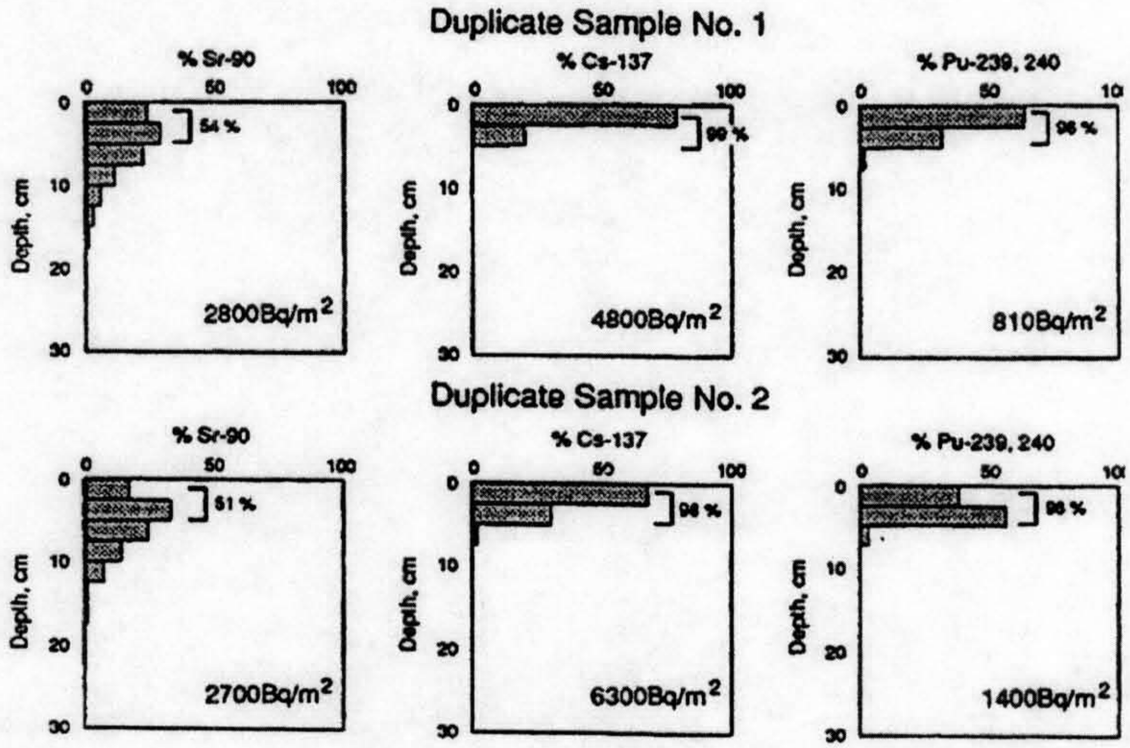


Table 3-8. Bruns' Report on Percent Activity vs. Depth in the Soil.

Depth in the Soil		Percent Activity	
Centimeters	**Inches**	**Strontium-90**	**Cesium-137**
0 - 2.5	0 - 1	47.0 (47)	60.0 (60)
2.5 - 5.0	1 - 2	31.0 (78)	25.5 (85.5)
5.0 - 10.0	2 - 4	17.5 (95.5)	12.2 (97.7)
10.0 - 15.0	4 - 6	3.5 (99)	1.8 (99.5)
15.0 - 20.0	6 - 8	0.9 (99.9)	0.4 (99.9)
20.0 - 30.0	8 - 12	0.1 (100)	<0.1 (100)
--	--	100	100

Bruns, L. E., 1974a, "Status of BC Crib Surface Contamination Development Work," Letter from Atlantic Richfield Hanford Company to H. L. Maxfield, Atlantic Richfield Hanford Company, July 11.

This shows about 96 percent of the Sr-90 in the top 4 in. and 99 percent in the top 6 in. It also shows 98 percent of the Cs-137 in the top 4 in. and greater than 99 percent in the top 6 in.

On the other hand, as discussed in Section 3.2.3, Bruns presents information on the total activity vs. depth for the area contaminated with animal waste. This information also allows one to calculate the percent activity vs. depth in the soil. This information is summarized in Table 3-9, "Total Activity vs. Depth for BC Cribs Area in 1973." This implies greater penetration of Sr-90 and Cs-137, down to about a foot.

Table 3-9. Total Activity vs. Depth for BC Cribs Area in 1973 (All Activities in Curies).

Depth (cm)	Cs-137	% Cs-137 Total	Sr-90	% Sr-90 Total	Total	% Total
0 – 1.0	5.0	34	20.0	25	25.0	26
1.0 – 2.5	3.0	21	13.5	17	16.5	17
2.5 - 5.0	2.5	17	12.5	15	15.0	16
5.0 – 10.0	2.0	14	16.0	20	18.0	19
10.0 – 20.0	1.5	10	12.0	15	13.5	14
20.0 – 30.0	0.5	3	7.5	9	8.0	8
Totals	14.5	--	81.5	--	96	--

Thus, the information in this report is not consistent, but it does not directly indicate activity deeper than about a foot.

3.5.2.2 Anecdotal Evidence

As mentioned in Section 2.7, there is some anecdotal evidence that radioactive material has been found deeper than 1 ft in the soil, even to a depth of 3 ft. R. E. Wheeler, in the "Semiannual Radiological Survey Summary for the Second Half of Fiscal Year 1984" (Wheeler 1984) reports extensive spotty contamination to 60 mrad/h in a burned area (after a range fire) at the intersection of Rockwell Street and Dupont Avenue. Cleanup of this area was attempted, but the contamination was found to be too extensive; the contamination was reported to have leached to 3 ft deep. In an interview with A. W. Conklin (see Appendix A), he also mentioned the attempt to clean up this area. Conklin reported that the soil was removed using shovels and 5-gal buckets, and after about 50 buckets, the workers gave up, because the contamination was deep into the soil and seemed to be getting more active as they dug deeper. Conklin also noted that this area did not show up on the airborne surveys as being contaminated; he speculated that this was because the contamination primarily was Sr-90 and would not be detected by the aerial survey (because Sr-90 and its daughter have no gamma emissions). W. L. Osborne and W. M. Hayward (see Appendix A) also mentioned the effort to decontaminate the small burned area and confirmed that large amounts of contaminated soil were found and the area was abandoned.

Thus, there is information in a report and in human memory suggesting that the contamination, at least at one location, is considerably deeper than a foot.

3.5.2.3 Related Information

"Movement of Radiostrontium in the Soil Profile in an Arid Climate" in *Health Physics* (Cline 1984) measured the change in the distribution of Sr-90 in soil after a period of 10 years. The initial distribution went down to about 25 cm and peaked at about 15 cm. After 10 years, the peak was about the same, but the distribution had flattened considerably: the maximum depth of penetration was about 44 cm. Thus, for this case with Sr-90, the distribution continued to change by natural processes long after it had well-penetrated the soil. Thus, the strontium (and probably other nuclides) distributions measured in the 1970s likely have changed with deeper distributions now, after 30 years.

BNWL-B-148 notes, "They pointed out, however, that because plutonium readily forms complexes which are difficult to remove from solution, such complexes would not be expected to be retained by soil." Thus, the plutonium dispersed by the animals might well have been complexed and might have penetrated the soil more deeply than is characteristic of plutonium fallout.

In general, the Sr-90 and Cs-137 were processed biologically and entered the soil as urine and feces. Such Sr-90 and Cs-137 may well have been biologically complexed, and their behavior in soil might well be much different than that which originated as weapons fallout and process stack discharges. Complexed material may well have penetrated much deeper.

Thus, for areas affected with animal waste, the penetration of Cs-137 and Sr-90 (and probably other nuclides) is at least a foot and likely deeper in many cases. From the available information, there is no way to determine the depth distributions at this time, and they will have to be measured.

3.6 RADIONUCLIDES OF CONCERN FOR THIS EFFORT

The BC Area was contaminated from two sources: airborne deposition from the 200 Areas and the biological transfer of activity from the BC Cribs and Trenches, primarily through animal urine and feces. Naturally occurring radionuclides and radionuclides from global fallout are not included.

The radionuclides of concern in the BC Area may be determined from a combination of theoretical considerations and historical observations. The theoretical considerations have been described in PNL-10060, *Identification of Radionuclides of Concern in Hanford Site Environmental Cleanup*. These may be supplemented by more recent work in support of ongoing risk assessments, specifically the 2004 iteration of the Hanford Site composite analysis. The primary source of historical observations is "Dose Rate Studies in the BC-Cribs Controlled Area – May and June 1973" (Bruns 1974b).

The theoretical calculations in PNL-10060 developed a set of radionuclides of concern that can be used as a starting point for a given case. They started with Oak Ridge Isotope GENeration and Depletion (ORIGEN2) runs that simulated the Hanford Site reactors and some special activities at the Site, and they derived a set of 27 radionuclides that, in general, should be considered by the subsequent consideration of the cleanup period at the Site, half-life of the radionuclides, external hazards of the radionuclides, and internal hazards of the radionuclides. The generic list of radionuclides that ought to be considered developed in PNL-10060 is presented in Table 3-10, "Radionuclides of Potential Concern Determined Theoretically."

Table 3-10. Radionuclides of Potential Concern Determined Theoretically.

Radionuclide	Half-Life, Years	Radionuclide	Half-Life, Years
H-3	12.35	Th-232	1.4×10^{10}
K-40	1.28×10^{9}	U-232	72
Co-60	5.27	U-233	1.59×10^{5}
Sr-90	29.12	U-234	2.45×10^{5}
Tc-99	2.13×10^{5}	U-235	7.038×10^{8}
Ru-106	1.008	Np-237	2.14×10^{6}
Sb-125	2.77	Pu-238	87.74
I-129	1.57×10^{7}	U-238	4.468×10^{9}
Cs-134	2.062	Pu-239	2.406×10^{4}
Cs-137	30	Pu-240	6537
Eu-152	13.6	Am-241	432.2
Eu-154	8.6	Pu-241	14.4
Eu-155	4.96	Cm-244	18.11
Ra-226	1600	--	--

Bruns (1974a) in "Status of BC Crib Surface Contamination Development Work," in 1973 and 1974 investigated the activities of other radionuclides in high-activity soils in the BC Cribs Area. In addition to Cs-137 and Sr-90, which were known to be present in significant quantities, Bruns noted these quantities of radionuclides in the soil: Pu-239/240: <0.1-1.3 x 10^{-10} g/g soil; Eu-155: 6.0 x 10^{-11} Ci/g (max); Co-60: 7.0 x 10^{-12} Ci/g (max); and Am-241: 1.0 x 10^{-10} Ci/g (max). Bruns also reported the presence of other radionuclides whose concentrations were not given but whose concentrations apparently were at levels that he considered small: Eu-154, U-238, U-235, Ru-103, Pu-238, Ru-106, Rh-106, Co-57, Sb-125, Ra-226, Cr-51, Sr-85, Eu-152, Cs-135, Ce-141, Th-228, K-40, and Ra-228. These detected radionuclides are listed in Table 3-11, "Radionuclides Detected in the BC Cribs Vicinity."

Recent evaluations have been made for inventories and important radionuclides in support of the 2004 iteration of the Hanford Site composite analysis, the update to PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Areas Plateau of the Hanford Site*. DOE Order 5820.2A, *Radioactive Waste Management*, and its replacement, DOE O 435.1, *Radioactive Waste Management*, require that site performance assessments and composite analyses be maintained by the Hanford Site. A composite analysis that supports waste disposal and remedial actions for the Hanford Site (PNNL-11800) was issued in 1998 and approved in 2000. The calculations are beginning for the 2004 iteration of the Hanford Site composite analysis, as required under the regulations. The composite analysis is a tool for evaluating the environmental impacts of all of the waste management sites at the Hanford Site at once.

Table 3-11. Radionuclides Detected in the BC Cribs Vicinity.

Radionuclide	Half-Life, Years	Radionuclide	Half-Life, Years
K-40	1.28×10^9	Eu-152	13.6
Cr-51	0.076	Eu-154	8.6
Co-57	0.744	Eu-155	4.96
Co-60	5.27	Ra-226	1600
Sr-85	0.178	Th-228	1.913
Sr-90	29.12	Ra-228	5.76
Ru-103	0.108	U-235	7.038×10^8
Rh-106	0.0002	Pu-238	87.74
Ru-106	1.008	U-238	4.468×10^9
Sb-125	2.77	Pu-239	2.406×10^4
Cs-135	2.3×10^6	Pu-240	6537
Cs-137	30	Am-241	432.2
Ce-141	0.089	--	--

Cumulative impact assessments provide a Sitewide context for the decisions that must be made on individual waste sites. In addition, this capability allows users to explore the potential impact of remediation alternatives, and, finally, it provides a way to visualize how the impact from various waste types remaining at the Hanford Site will overlap across time.

The 2004 composite analysis will use the newly developed system assessment capability (SAC) as its basic tool. The SAC recently was used in a preliminary mode (PNNL-14027, *An Initial Assessment of Hanford Impact Performed with the System Assessment Capability*) to demonstrate its capabilities and establish requirements for enhancements for the composite analysis. For this demonstration, the resident farmer scenario was used as the basis for estimating impacts on human health. The resident farmer scenario has evolved from that used in DOE/RL-96-16, *Screening Assessment and Requirements for a Comprehensive Assessment: Columbia River Comprehensive Impact Assessment*, and now is proposed for use in evaluating soil contamination across the Hanford Site (PNNL-14041, *Recommendations for User Supplied Parameters for the RESRAD Computer Code for Application to the Hanford Reach National Monument*).

The composite analysis is focused largely on the groundwater, but to evaluate the impacts, source terms have been developed for all sites. These source terms contain many radionuclides;

some are treated explicitly in the composite analysis models and others (noted in Table 3-12, "Radionuclides of Potential Concern for the BC Area") are assumed to be in various stages of equilibrium with the parent in their decay chain. In particular, a significant amount of Tc-99 was released in the BC Cribs Area; this highly mobile radionuclide has large uptake factors for plants and animals, and likely is to require analysis in the contaminated surface soils. Although I-129 has similar biological and transport properties, its inventory in the BC Cribs is only on the order of a few curies. The radionuclides considered in the composite analysis are listed in Table 3-12.

Table 3-12. Radionuclides in the BC Cribs Area Considered in the Upcoming Composite Analysis.

Radionuclide	Half-Life, Years	Included in 2004 Composite Analysis?
H-3	12.35	Yes
Sr-90	29.12	Yes
Tc-99	2.13×10^5	Yes
I-129	1.57×10^7	Yes
Cs-137	30	Yes
Eu-152	13.6	Yes
Ra-226	1600	(only as progeny)
U-233	1.59×10^5	Yes
U-234	2.45×10^5	(implicit)
U-235	7.038×10^8	Yes
Np-237	2.14×10^6	Yes
U-238	4.468×10^9	Yes

Various reasons exist for including or excluding radionuclides from Tables 3-10, 3-11, and 3-12. These reasons are discussed for each potential contributor.

- Tritium is highly volatile, and was generally released as tritiated water (i.e., as a form of water). It is no longer expected to be present in surface soils at the site.
- K-40 is not a fission product. It is present in background. Significant contamination by anthropogenic K-40 is unlikely.
- Many radionuclides that historically have been measured in the BC Cribs Area have short half-lives. The most recent extensive monitoring was about 30 years ago; radionuclides with half-lives less than about 5 years have largely decayed. Some, such as Co-60 and Eu-152, have sufficiently high gamma decay energies that even though they are no longer present in large quantities, they may still act as viable tracers for contamination. Therefore, with the exception of Co-60 and Eu-152, short-lived radionuclides (Cr-51, Co-57, Sr-85, Ru/Rh-103, Ru/Rh-106, Sb-125, Cs-134, Ce-141, Eu-154, and Eu-155) have been omitted.

- I-129 has a minimal inventory on site; it primarily is a groundwater problem.
- Many other radionuclides that have been reported historically are members of the naturally occurring uranium or thorium decay chains (e.g., Th-228, Ra-226). Because U-232, U-233, and Th-232 were not disposed of in large inventories (according to SAC inventories prepared for DOE/EIS-0286D, *Draft Hanford Site Solid (Radioactive and Hazardous) Waste Program Environmental Impact Statement, Richland, Washington*), they and their decay progeny need not be specially accounted for. This includes Ra-226, which may grow in over millennia from decay of the U-238 chain. Its contribution to dose may be included in the future calculations based on U-238 concentrations.
- Others of the historically monitored radionuclides also are members of longer chains. U-234 eventually will equilibrate with U-238, and a significant portion of Pu-241 already has decayed to the more-easily-detected Am-241.
- Pu-239/240 will be present in mass ratios approximately equivalent to those in weapons-grade plutonium (about 6 percent Pu-240). Because they have very similar alpha decay energies, they usually are combined in monitoring results. The dominant exposure pathway for these radionuclides in surface soils tends to be resuspension and inhalation.
- Pu-238 was not disposed in significant quantities in this waste stream.
- Large quantities of uranium were disposed of; the primary radionuclide by mass will be U-238. The wastes may be assumed to be slightly depleted in the fissionable isotope U-235.
- The radionuclide Np-237 frequently appears as a fractional contributor in environmental assessments involving nuclear wastes. This radionuclide has moderate transport characteristics, and the highest biological transfer rates of the actinides (PNNL-13421, *A Compendium of Transfer Factors for Agricultural and Animal Products*).
- Higher actinides such as curium have relatively low inventories in the low-burnup fuels used for nuclear materials production.

As a result of these considerations, a list of 11 radionuclides of concern has been generated (see Table 3-13, "Radionuclides of Potential Concern for the BC Area"). Each of the radionuclides of concern is accompanied by a description of why it is included. The other radionuclides presented in Tables 3-10 through 3-12 were omitted for the reasons discussed above.

Table 3-13. Radionuclides of Potential Concern for the BC Area.

Radionuclide	Half-Life (Years)	Brief Reason for Inclusion
Co-60	5.27	Half-life short, but initially in crib and trench waste in substantial quantities. External gamma exposure. Energetic gammas; can be used as a tracer.
Sr-90	29.12	The major long-lived constituent of the crib and trench waste. A major dose-contributing radionuclide at the Hanford Site: primary source of internal dose.
Tc-99	2.13×10^5	BC Cribs and Trenches contain the largest inventory disposed to soil. Large biological transfer factors.
Cs-137	30	A major constituent of BC Crib and Trench waste. A major dose-contributing radionuclide at the Hanford Site.
Eu-152	13.6	External gamma exposure. Energetic gamma; can be used as a tracer.
U-235	7.04×10^8	Uranium disposed of to the BC Cribs and Trenches.
Np-237	2.14×10^6	Potentially high mobility and biological availability. Has highest biological transfer rates of the actinides.
U-238	4.47×10^9	Primary uranium isotope. Large quantities of uranium disposed of in the BC Cribs and Trenches.
Pu-239	2.41×10^4	Known to be present. Alpha energy similar to Pu-240 and usually combined in analysis.
Pu-240	6537	Known to be present. Alpha energy similar to Pu-239 and usually combined in analysis.
Am-241	432.2	Daughter of Pu-241 and more easily detected than Pu-241.

3.7 NATURE OF THE CONTAMINATION AND THE DEGREE OF TRANSFERABILITY

3.7.1 Description of the Contamination

The contamination generally is believed to be bound to the soil. Most of the urine and feces was deposited before 1970 (prior to the trenches being covered in 1969) and the physical material has long since decayed and the contamination absorbed by the soil. Most of the plant matter was deposited before the stabilization in 1982, and it, too, has decayed and been absorbed by the soil.

Mobile plant contamination, largely tumbleweed, could be a whole plant, a branch, or a piece so small, such as a seed, as to be difficult to see. If this is still in the form of a plant, it will be on the surface. Animal contamination might be feces, urine spots, or radioactive bones of small animals.

3.7.2 Degree of Transferability of the Contamination

The tendency of the contamination to stick to surfaces such as shoes and equipment has been noted to be low for 30 years. ARH-3088 (1974) noted the following:

> "During the past 12 years, many entries have been made by man to accomplish work in the B-C Cribs Controlled Area. Radiation monitors have continued to inspect and take vegetation and soil samples from the area; telephone and electrical line workers have routinely entered to do maintenance work; biological field research teams have entered the zone on numerous occasions; and construction forces used heavy earth-moving equipment to cut out and construct 10 ½ miles of fire protection roads throughout the area. In all cases, radiation surveys for release from the zone showed personnel, tools and equipment to be free from radioactive contamination, (Appendix C)."

Even given that standards were probably less stringent in 1974 than now, this statement, made in a major decision report, does not suggest serious contamination control problems. Firebreaks were cut right through the area of highest contamination at a time when there still were visible rabbit pellets. In addition, much of the biological research work and soil sampling and measurements were carried out in the areas of highest contamination.

Barry Headley, who worked as a health physics technician in the BC Area during the period 1991-2001 and who did many surveys in the area, reported that he never found any contamination on people and equipment coming out of the contaminated area and that the contamination does not stick (see Appendix A).

David Ellingson, David Phipps, and Keith Yates (see Appendix A) noted that contamination in the soil only sticks to shoes and other surfaces if the soil or biological material in which the contamination exists actually sticks to the surface. For instance, dry, sandy soil does not stick to shoes and does not result in transferable contamination; however, if the soil is wet and muddy and the mud sticks to the shoes, then if there is contamination in the mud, it will be on the shoes. In addition, dry tumbleweed contamination will not transfer directly (only if the soil itself clings to the surface); however, green tumbleweed sap can be contaminated. Curtis Eggemeyer (see Appendix A) noted that he did not ever recall finding transferable contamination during his work in the BC Area, largely in the area of the firebreak roads.

In 1999, BHI performed studies of the transferability of the contamination in the BC Area. The plans for and results of this study are described in BHI-01225 and BHI-01319. Points that showed high count rates on the transect survey were chosen for the test. If the transferable alpha contamination exceeded 20 dpm/100 cm^2 or the transferable beta-gamma contamination exceeded 1,000 dpm/100 cm^2, the contamination was considered transferable. The locations of the points where the transferability tests were made are shown in Figure 3-9, "1999 Transferability Sampling Locations and Surface Soil Sampling Locations." Headley (see

Figure 3-9. 1999 Transferability Sampling Locations and Surface Soil Sampling Locations.

Appendix A), who conducted the actual tests, described the tests: Wearing boots with lugged, Vibram[1] soles, he walked through a 3 m circle eight times, dragging his feet as though he was very tired; the boots then were surveyed for contamination. If contamination was found, no further work was done at that spot. If no contamination was found, then 10 gal of water were poured on the ground and he repeated the walk-through procedure. The boots again were examined for contamination. The results of this work are shown in Table 3-14, "Results of 1999 Contamination Transferability Study." As can be seen, in all cases, as the test became increasingly severe (dry soil on boots to wet soil on boots), the contamination exceeded the allowable levels in all cases. Note that all of the study locations are in the Northern BC Controlled Area. As can be seen, this test was severe and does not reflect the activities and conditions usually found in the field; i.e., it is not representative of the actual conditions in the field. The results of this text contradict the results of years of field experience.

Table 3-14. Results of 1999 Contamination Transferability Study.

Survey Point	Sample Type	Exceeded Transferable Limit Wet	Exceeded Transferable Limit Dry	Direct Measurement on Soil	Transect Survey Result Net cpm Gamma	Alpha (dpm)	Beta-Gamma (dpm)
1	Boot	Yes	--	--	4246	<20	2400
2	Boot	--	Yes	--	2403	<20	1500
3	Boot	--	Yes	--	4884	<20	2100
4	Boot	--	Yes	--	7721	<20	6840
5	Boot	Yes	--	--	2415	<20	1560
6	Soil	--	--	Yes	4461	<100	70,980
7	Boot	Yes	--	--	2036	<20	2400
8	Soil	--	--	Yes	5607	<100	59,280
9	Boot	--	Yes	--	19,926	<100	9,600
10	Boot	--	Yes	--	10,379	<100	22,800

cpm = counts per minute.
dpm = disintegration per minute.

3.7.3 Summary Discussion

From the review above, it can be seen that the almost all of the contamination is bound to the soil. Relatively rare (now) examples of tumbleweed fragments and feces still might be found. Furthermore, observers, over a period of 30 years, have reported that the contamination in the BC Area does not transfer to surfaces, even during periods of extensive activity in the areas of highest soil contamination. Barry Headley, in tests designed to get contamination to stick to boots if possible, reported that dry contamination would adhere lightly to boots, but would drop off with slight movements, such as tapping the boots together. If the soil was mixed with water

[1]Vibram is a trademark of the Vibram Corporation.

to become muddy and the mud gets on the surfaces, the contamination in the mud will be detectable. Given the historical results, such a circumstance must be quite unusual. In summary, the contamination will not adhere to any degree to surfaces during normal work activities, except in the rare circumstance when there is high contamination in muddy areas.

3.8 SOIL SAMPLE RESULTS

3.8.1 1999 Surface Soil Samples in the Northern BC Controlled Area

The results of surface soil samples taken in 1999 from the top 1 cm of soil are given in Table 3-15, "1999 Bechtel Hanford, Inc., Surface Soil Sample Results." The sampling locations are shown in Figure 3-9. These results are taken from BHI-01319. The negative values given for some activity concentrations are a result of the sample count being less than the background count due to random fluctuation in counts. The values in these table are reported as given in the reference. The reference did not provide an explanation for the symbol "U." The symbol "--" is used here to indicate a blank cell in the original table.

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results. (6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Sample: S-1. BHI Sample ID: BOVY60		
Pu-238	0.02	0.049
Pu-239/240	0.58	0.038
Am-241	0.185	0.043
Sr	1100	0.14
Co-60	U	0.055
Cs-137	787	0.23
Eu-152	U	0.86
Eu-154	0.278	0.15
Eu-155	U	0.63
U-238	U	6.3
U-235	U	1
Sample: S-2. BHI Sample ID: BOVY62		
Pu-238	-0.004	0.042
Pu-239/240	0.065	0.047
Am-241	0.029	0.035
Sr	196	0.15

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results.
(6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Co-60	--	0.028
Cs-137	94.6	0.094
Eu-152	--	0.37
Eu-154	--	0.1
Eu-155	--	0.3
U-238	--	3.8
U-235	--	0.47
Sample: S-3. BHI Sample ID: BOVY64		
Pu-238	0.008	0.043
Pu-239/240	0.071	0.048
Am-241	0.038	0.032
Sr	201	0.14
Co-60	U	0.027
Cs-137	71.6	0.073
Eu-152	U	0.24
Eu-154	U	0.098
Eu-155	U	0.18
U-238	U	3.3
U-235	U	0.3
Sample: S-4. BHI Sample ID: BOVY66		
Pu-238	0.025	0.059
Pu-239/240	0.062	0.059
Am-241	0.019	0.047
Sr	152	1.1
Co-60	U	0.014
Cs-137	64	0.042
Eu-152	U	0.15
Eu-154	U	0.048
Eu-155	U	0.12
U-238	U	1.8
U-235	U	0.2

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results. (6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Sample: S-5. BHI Sample ID: BOVY68		
Pu-238	-0.004	0.063
Pu-239/240	0.063	0.043
Am-241	0.022	0.048
Sr	203	1.4
Co-60	U	0.025
Cs-137	69.4	0.079
Eu-152	U	0.29
Eu-154	U	0.092
Eu-155	U	0.24
U-238	U	3.4
U-235	U	0.38
Sample: S-6. BHI Sample ID: BOVY70		
Pu-238	-0.007	0.032
Pu-239/240	0.043	0.032
Am-241	0.021	0.04
Sr	88.8	0.48
Co-60	U	0.018
Cs-137	41.3	0.048
Eu-152	U	0.17
Eu-154	U	0.063
Eu-155	U	0.13
U-238	U	2.3
U-235	U	0.22
Sample: S-7. BHI Sample ID: BOVY72		
Pu-238	0.049	0.046
Pu-239/240	1.85	0.036
Am-241	0.918	0.06
Sr	3420	9.2
Co-60	U	0.12
Cs-137	2290	0.96

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results.
(6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Eu-152	U	2.9
Eu-154	U	0.42
Eu-155	U	2.2
U-238	U	20
U-235	U	3.2
Sample: S-8. BHI Sample ID: BOVY74		
Pu-238	-0006	0.051
Pu-239/240	0	0.049
Am-241	0.021	0.075
Sr	0.664	0.25
Co-60	U	0.017
Cs-137	0.494	0.014
Eu-152	U	0.043
Eu-154	U	0.055
Eu-155	U	0.054
U-238	U	2.1
U-235	U	0.07
Sample: S-9. BHI Sample ID: BOVY76		
Pu-238	-0.006	0.043
Pu-239/240	0	0.036
Am-241	-0.008	0.052
Sr	0.318	0.23
Co-60	U	0.02
Cs-137	0.347	0.023
Eu-152	U	0.04
Eu-154	U	0.07
Eu-155	0.031	0.036
U-238	U	2.4
U-235	0.056	0.061

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results. (6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Sample: S-10. BHI Sample ID: BOVY78		
Pu-238	0.008	0.045
Pu-239/240	0.028	0.031
Am-241	0	0.06
Sr	1.13	0.13
Co-60	U	0.025
Cs-137	0.566	0.023
Eu-152	U	0.068
Eu-154	U	0.09
Eu-155	U	0.068
U-238	U	3.1
U-235	U	0.1
Sample: S-11. BHI Sample ID: BOVY80		
Pu-238	-0.007	0.063
Pu-239/240	0.038	0.038
Am-241	0.009	0.082
Sr	24.6	0.17
Co-60	U	0.027
Cs-137	3.8	0.034
Eu-152	U	0.075
Eu-154	U	0.098
Eu-155	U	0.07
U-238	U	3.2
U-235	U	0.11
Sample: S-12. BHI Sample ID: BOVY82		
Pu-238	0.008	0.048
Pu-239/240	0.035	0.037
Am-241	0.035	0.073
Sr	1.1	0.12
Co-60	U	0.027
Cs-137	1.49	0.032

Table 3-15. 1999 Bechtel Hanford, Inc., Surface Soil Sample Results.
(6 Pages)

Radionuclide	Result (pCi/g)	MDA (pCi/g)
Eu-152	U	0.073
Eu-154	U	0.083
Eu-155	U	0.07
U-238	U	3
U-235	U	0.1
Sample: S-13. BHI Sample ID: BOVY84		
Pu-238	0.01	0.053
Pu-239/240	0.056	0.027
Am-241	0.035	0.027
Sr	2.24	0.14
Co-60	U	0.027
Cs-137	0.748	0.031
Eu-152	U	0.071
Eu-154	U	0.087
Eu-155	U	0.075
U-238	2.95	0.1
U-235	U	3.4

BHI = Bechtel Hanford, Inc.
ID = identification.
MDA = minimum detection activity.

An examination of these data shows that strontium surface soil concentrations vary by a factor of about 10,700 (0.32 to 3420 pCi/g) across the area sampled. Cs-137 surface soil concentrations vary by a factor of about 6,500 (0.35 to 2290 pCi/g) across the area. Pu-239/240 surface soil concentrations vary by a factor of about 65 (0.028 to 1.85 pCi/g). Thus, the surface soil concentrations of strontium and Cs-137, the two radionuclides likely to deliver the most dose to an occupant, vary widely across the Northern BC Controlled Area.

3.8.2 Soil Samples Related to the Southern BC Controlled Area

There are some results of soil samples in the area of the Southern BC Controlled Area that are of some use in determining the present level of contamination.

The results of some long-term soil sampling on the Hanford Site and vicinity are given in PNNL-11673, *Historical Review of Long-Term Soil Sampling for Environmental Surveillance at* *the Hanford Site and Vicinity*. One point, designated 200 ESE, is about a half-mile east of the southeast corner of the 200 East Area (near the abandoned gun emplacement), which would provide an indication of the expected soil concentrations in the Southern BC Controlled Area. Because this site is much closer to the 200 East Area, one would not expect the values in the Southern BC Controlled Area to exceed these values. The values report for some recent years, all in the top 1 in. of soil, are given in Table 3-16, "Results of Soil Samples from Location 200 East Southeast (pCi/g)."

Table 3-16. Results of Soil Samples from Location 200 East Southeast (pCi/g).

Year	Sr-90	Cs-137	Pu-238	Pu-239/240
1985	0.197	0.55	0.0005	0.0216
1986	0.27	0.373	0.0004	0.0084
1987	0.238	0.613	0.0004	0.0118
1988	0.589	1.62	0.0011	0.0356
1989	0.125	0.587	0.0005	0.0105
1991	0.173	0.408	0.0002	0.008
1992	0.17	0.52	0.0004	0.0108
1993	0.183	0.424	0.0004	0.0136
Max Value	0.589	1.62	0.0011	0.0356
Average	0.24	0.64	0.0005	.0.015

Note that the highest value reported for each nuclide was reported in 1988.

The results of some soil samples in the area near the BC Controlled Area are given in WHC-EP-0771. Of the locations' samples, those labeled "A0-AX" and "B0-B5" would be most indicative of the Southern BC Controlled Area. The results are given in Table 3-17, "Soil Sample Results in WHC-EP-0771 Near the Southern BC Controlled Area (pCi/g)." The negative values given for some activity concentrations are a result of the sample count being less than the background count due to random fluctuation in counts.

Table 3-17. Soil Sample Results in WHC-EP-0771 Near the Southern BC Controlled Area (pCi/g). (2 Pages)

Location	Sr-90	Cs-137	Pu-238	Pu-239/240
A0	0.18	0.63	-0.003	0.010
A2	0.22	0.46	No Value	0.010
A3	0.17	0.27	No Value	0.010
A4	0.18	0.28	No Value	0.020
A5	0.57	0.86	No Value	0.030
AX	0.38	0.52	No Value	0.010
B0	0.23	0.74	No Value	No Value

Table 3-17. Soil Sample Results in WHC-EP-0771 Near the Southern BC Controlled Area (pCi/g). (2 Pages)

Location	Sr-90	Cs-137	Pu-238	Pu-239/240
B1	0.19	0.48	No Value	0.010
B2	0.17	0.54	No Value	No Value
B3	0.10	0.27	No Value	0.010
B4	0.20	0.24	No Value	No Value
B5	0.16	0.87	No Value	0.010
Max Value	0.57	0.87	No Value	0.030
Average	0.23	0.51	No Value	0.012

WHC-EP-0771, 1994, *Comparison of Radionuclide Levels in Soil, Sagebrush, Plant Litter, Cryptogams, and Small Mammals*, D. S. Landeen, A. R. Johnson, R. M. Mitchell, and M. R. Sackschewsky, September.

Some Washington State Department of Health data for soil samples taken on Army Loop Road are given in DOE/RL-95-55, *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data*. The sampling point, designated as 13DOH, appears to lie slightly to the west of the 200 East Area on Army Loop Road. The results given are summarized in Table 3-18, "Soil Data from Washington State Department of Health Site 13DOH on Army Loop Road (pCi/g)."

Table 3-18. Soil Data from Washington State Department of Health Site 13DOH on Army Loop Road (pCi/g).

Year	Sr-90	Cs-137	Pu-238	Pu-239/240	Co-60	Ru-106
1987	0.0996	0.109	0.000188	0.00720	No value	No value
1988	0.0196	0.0684	0.00123	0.00260	No value	No value
1989	0.0323	0.0657	0.00191	0.000500	-0.000940	0.000639
1990	0.0196	0.0672	0.0135	0.000900	0.00750	0.00127
Maximum	0.0996	0.109	0.0135	0.00720	0.00750	0.00127
Average	0.0428	0.0776	0.0042	0.0028	0.00750	0.0010

Given the locations where these data were taken and their proximity to the Southern BC Controlled Area, the results from Table 3-17 are the most representative. Thus, the best estimates of the average and maximum contamination events in the Southern BC Controlled Area for the primary radionuclides are the ones given in Table 3-17.

4.0 CONCEPTUAL MODELS OF RADIOACTIVE CONTAMINATION FOR THE BC CONTROLLED AREA

This chapter discusses the specific conceptual models of radioactive contamination in the BC Controlled Area that have resulted from the detailed review of the site history and other radiological information that is given in Chapters 2.0 and 3.0. There is no conceptual model for the BC Cribs and Trenches Area, because the intent now is to cover this area with a heavy, impermeable barrier. Radiological characterization is needed for this area only for occupational radiation protection purposes. The conceptual models essentially provide a picture of the contamination, both its type and distribution. They also point out any shortcomings in the available information, so that they can be accounted for in the survey plans. The conceptual models provide the bases upon which to develop survey plans.

For the purposes of this report, the conceptual model of radioactive contamination consists of these elements:

1. A description of the area to which the model applies
2. A description of the degree of uniformity of the contamination
3. An assessment of the stability of the contamination
4. A list of the radionuclides of concern
5. Estimates of the concentrations of activity in the area
6. A description of the soil depth profile of the radionuclides
7. An assessment of the degree to which the contamination in the soil is "transferable" to clothing and equipment
8. Initial assessment as impacted or not impacted, in accordance with the criteria given in MARSSIM, Revision 1.

4.1 SOUTHERN BC CONTROLLED AREA

The Southern BC Controlled Area is contaminated from three sources: global fallout; airborne deposition from activities in the 200 Area; and probably rare points of biologically transported contamination, such as tumbleweed fragments and urine and feces from crossing animals that had been contaminated elsewhere. The concentrations of the radionuclides are the levels that are characteristic of the soil in the 200 Area Plateau. Any biologically transported contamination primarily is Cs-137 and Sr-90.

4.1.1 Area to Which the Model Applies

The Southern BC Controlled Area essentially is the area south of the band of sand dunes that crosses the controlled area from east to west; the exact boundaries of the Southern BC Controlled Area are shown in Figure 4-1, "Southern BC Controlled Area." The Southern BC Controlled Area is distinguished from the northern area by the general lack of biologically transported radioactive material. The Southern BC Area has an area of about 5.2 mi^2.

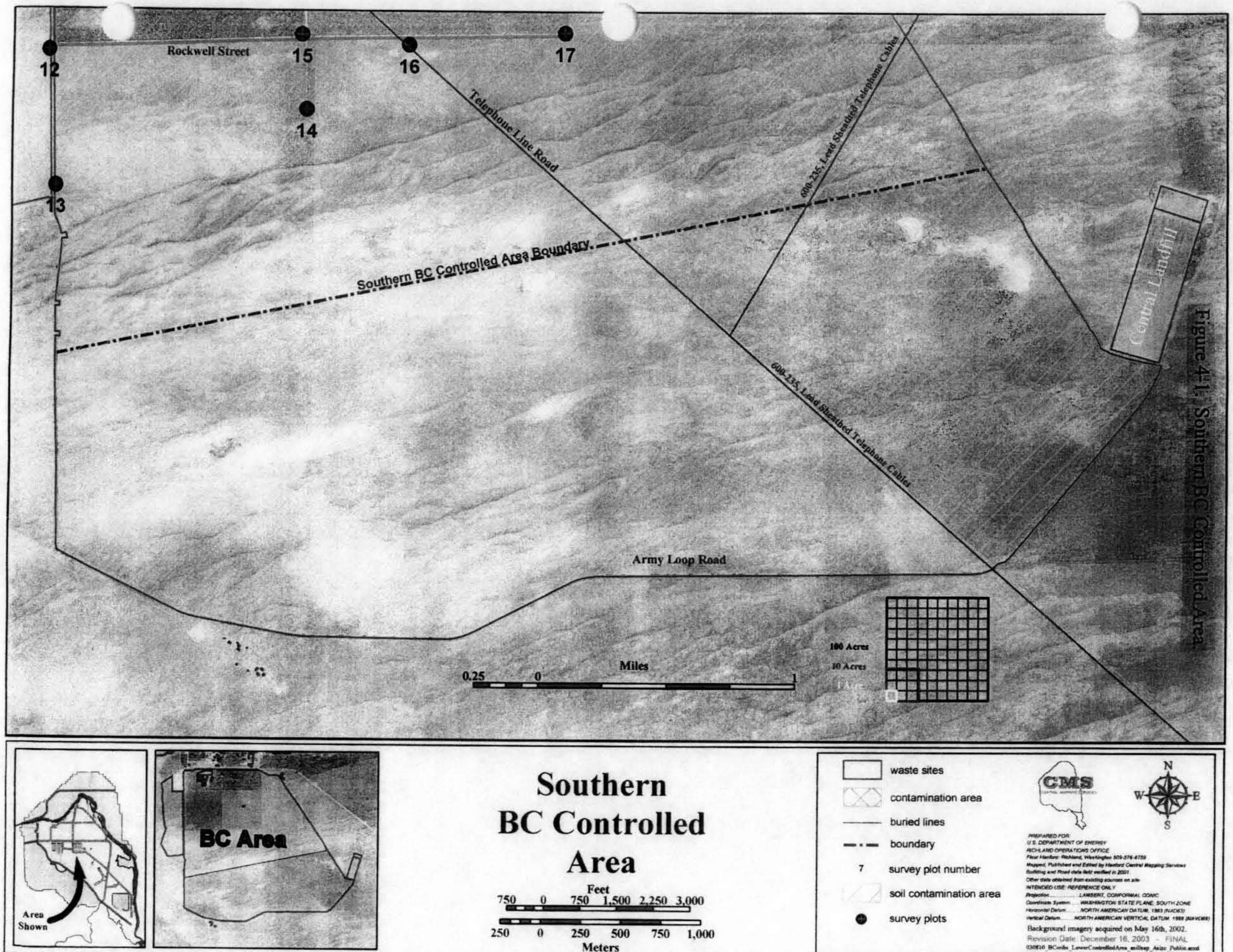


Figure 4-1. Southern BC Controlled Area

4.1.2 Degree of Uniformity of the Contamination

The general area contamination is largely uniform across the Southern BC Controlled Area, with variations characteristic of global fallout and the 200 Area Plateau. A gradual change may exist in the general activity levels, but large areas with radically different general activity levels do not exist. The biological contamination is in the form of small spots, from specks to urine spots about 12 in. in diameter and 6 in. deep. The biological contamination is distributed randomly throughout the area; the degree of the biological contamination has not been determined, but it is believed to be sparse.

4.1.3 Stability of the Contamination

The contamination is stable across the area. The contaminated area is not known to be generally moving. There could be small amounts of blowing or biologically transported activity, but these would be quite small and not significant to the characterization of the area. Section 3.3 discusses the potential spread of contamination by various mechanisms.

4.1.4 Radionuclides of Concern

The radionuclides of concern are Cs-137, Sr-90, Pu-239/240, Co-60, Tc-99, Eu-152, U-235, Np-237, U-238, and Am-241. The primary radionuclides of concern—those expected to deliver almost all of dose—are Cs-137, Sr-90, and Pu-239/240. Radionuclides of concern are discussed in Section 3.6 and summarized in Table 3-13.

4.1.5 Concentrations of Activity in the Area

The estimated concentrations of the primary radionuclides in the general areas are as follows:

- Cs-137: 0.9 pCi/g
- Sr-90: 0.6 pCi/g
- Pu-239/240: 0.03 pCi/g.

These concentrations are discussed in Section 3.8.2 and summarized in Table 3-17.

4.1.6 Soil Depth Profile of the Radionuclides

For the general contamination (excluding spots of biological contamination), the primary radionuclides of concern are in the top 1 in. of soil, except for Sr-90, which is distributed down about 6 in. with the top inch containing about 40 percent of the Sr-90. The soil depth profiles for Sr-90, Cs-137, and Pu-239/240 are those given by "The Depth Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples" in *Radiochimica Acta* (Price 1991). These depth profiles are discussed in Section 3.5.1 and shown in Figure 3-8.

4.1.7 Degree of Transferability

The activity in the soil is not transferable under normal conditions of dry or moist soil. It only is transferable if it is muddy and clumps of soil physically adhere to the surfaces. Incidents of contamination transferring (adhering to surfaces long enough to be moved offsite) to surfaces such as shoes and tools are rare. The evidence related to the transferability of activity in soil is discussed in Sections 3.7.2 and 3.7.3.

4.1.8 Initial Assessment as Impacted or Not Impacted

The initial classification of this area is impacted, Class 3. A Class 3 area is defined in MARSSIM, Revision 1, as "any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual radioactivity at a small fraction of the derived concentration guideline level Wilcoxon (DCGLw), based on site operating history and previous radiation surveys. Examples of areas that might be classified as Class 3 include buffer zones around Class 1 or Class 2 areas, and areas with very low potential for residual contamination but insufficient information to justify a non-impacted classification."

4.2 NORTHERN BC CONTROLLED AREA

The Northern BC Controlled Area is essentially the area north of the southern boundary of sand dunes that crosses the controlled area from east to west, not including the BC Cribs and Trenches Area itself. The Northern BC Controlled Area is distinguished from the Southern BC Controlled Area described above by the known presence of heavy biologically spread contamination or the reasonable likelihood of biologically spread contamination.

4.2.1 Area to Which the Model Applies

The Northern BC Controlled Area is shown in Figure 4-2, "Northern BC Controlled Area." The Northern BC Controlled Area has an area of about 8.2 mi^2. NOTE: The presence of the survey plot locations on the map is just incidental to the process used to make this map, because they were on the base map.

4.2.2 Degree of Uniformity of the Contamination

The degree of contamination is highly variable across the Northern BC Controlled Area: it ranges from areas of essentially continuous, heavy contamination to areas of broken contamination to areas that are contaminated only with global fallout and airborne contamination from the 200 Area (like the Southern BC Controlled Area described above). Strontium-90 concentrations in the surface soil vary by at least four orders of magnitude, Cs-137 concentrations in the surface soil vary by at least 3 orders of magnitude, and Pu-239/240 concentrations vary by at least an order of magnitude. As shown in Figure 2-16, Maxfield's Zone A (ARH-3088) has a very high density of contaminated spots and essentially is continuously contaminated; Zone B is largely heavily contaminated with areas contaminated only by 200 Area deposition and local movement of contamination dispersed within it. The area outside of Zone B has areas of contamination, best shown by Figure 2-7, interspersed with areas of less contamination. Spotty contamination exists outside the contours shown on Figure 2-7; this contamination likely decreases with distance from the most contaminated area. The contamination to the west continues to the western boundary of the BC Controlled Area (south and west of U.S. Ecology) and probably beyond. The spotty contamination to the east of Dupont Avenue probably contains a large concentration of Sr-90, relative to the Cs-137 level. There is spotty contamination inside the dune belt to the south. Information bearing on the uniformity of the contamination is presented in Chapters 2.0 and 3.0.

Figure 4-2. Northern BC Controlled Area.

4.2.3 Stability of the Contamination

The contamination is essentially stable. The contamination shows no evidence of large-scale movement; there is some movement within local areas. Local area movement likely would not be significant to the overall characterization of the area. Section 3.3 discusses the potential spread of contamination by various mechanisms.

4.2.4 Radionuclides of Concern

The radionuclides of concern are Cs-137, Sr-90, Pu-239/240, Co-60, Tc-99, Eu-152, U-235, Np-237, U-238, and Am-241. The primary radionuclides of concern—those expected to contribute the most dose—are Cs-137, Sr-90, and Pu-239/240. Radionuclides of concern are discussed in Section 3.6 and summarized in Table 3-13.

4.2.5 Concentrations of Activity in the Area

The concentrations of radioactivity within the area vary widely. The range of the surface concentrations of the primary radionuclides of concern are as follows:

- Cs-137: 0.2-3,000 pCi/g
- Sr-90: 0.1-4,000 pCi/g
- Pu-239/240: 0.01-2 pCi/g.

Section 3.8.1 discusses the basis for these values.

4.2.6 Soil Depth Profile of the Radionuclides

The soil depth profiles of the activity are expected to vary greatly due to the variation in the amount of urine and feces in a given area.

1. Areas with biological contamination: The maximum depths are difficult to estimate; the depths of the Cs-137 and the Sr-90 are at least 12 in. and may be greater. It is probable that the bulk of the activity is in the top 6 to 9 in. of soil; however, the possibility exists that the activity could be to the depth of 3 ft or greater in some areas. The ratio of Sr-90 concentration to Cs-137 concentration increases with depth into the soil and can reach 15 or greater.

2. Areas with no biological contamination: For the areas with non-biological contamination, the radionuclides are in the top 1- in. of soil, except for Sr-90, which is distributed down about 6 in. with the top inch containing about 40 percent of the Sr-90. The soil depths profiles for Sr-90, Cs-137, and Pu-239/240 are those given by "The Depth Distribution of Sr-90, Cs-137, and Pu-239/240 in Soil Profile Samples" in *Radiochimica Acta* (Price 1991).

These depth profiles are discussed in Section 3.5.1 and shown in Figure 3-8.

4.2.7 Degree of Transferability

The activity in the soil is not transferable under normal conditions of dry or moist soil. It only is transferable if it is muddy and clumps of soil physically adhere to the surfaces. Incidents of contamination transferring (adhering to surfaces long enough to be moved offsite) to surfaces such as shoes and tools will be rare. Sections 3.7.2 and 3.7.3 discuss the evidence related to the transferability of activity in soil.

4.2.8 Initial Assessment as Impacted or Not Impacted

The initial classification of this area is impacted, Class 1. A Class 1 area is defined in MARSSIM, Revision 1, as "areas that have, or had prior to remediation, a potential for radioactive contamination (based on site operating history) or known contamination (based on previous radiation surveys) above the $DCGL_W$. Examples of class 1 areas include: (1) site areas previously subjected to remedial actions, (2) locations where leaks or spills are known to have occurred, (3) former burial or disposal sites, (4) waste storage sites, (5) areas with contaminants in discrete pieces of material with high specific activity."

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5.0 OTHER USEFUL INFORMATION

More than radionuclide concentrations are needed to determine the expected dose from radionuclides in the soil due to Hanford Site activities. For instance, the radionuclides in the soil from weapons fallout do not result from Hanford Site activities (not directly, anyway), and the dose from them is not counted against the annual limit. Thus, it is useful to determine what fraction of the measured radionuclides are due to fallout. In addition, to calculate the dose using the accepted computer code, RESRAD, it is necessary to determine the appropriate values for a large number of user-defined values in the code; many of these values are specific to the soil-type and climate of the area.

5.1 RADIONUCLIDE BACKGROUND CONCENTRATIONS

PNL-10728, *Radionuclide Concentrations in Terrestrial Vegetation and Soil on and Around the Hanford Site, 1983 Through 1993*, determined suitable values for the background concentrations of radionuclides commonly found in the soil at the Hanford Site. These values, except for the uranium values, are determined from the measured values in soil at sites with a similar latitude and climate to the Hanford Site, such as Prosser and Yakima, and far enough away that they are unlikely to be affected by Hanford Site emissions. These values then are due to worldwide fallout and would be expected to be very similar to those at the Hanford Site. See Table 5-1, "2002 Estimates of Hanford Site Background Concentrations (pCi/g) Based on Decay-Corrected Soil Surveillance Data," for a summary of these values.

For more detail, including standard deviations and maximum values found, see PNNL-14046, *Evaluation of Radionuclide Concentrations in Support of Radiological Release of the WNP-1 and WNP-4 Sites at Hanford*, Chapter 3, "Hanford Site Background Radionuclide Concentrations in Soil: Estimates for Radionuclides of Interest at the WNP-1 and WNP-4 Sites."

5.2 HANFORD SITE-SPECIFIC RESRAD FACTORS

PNNL-14041 determined Hanford Site-specific RESRAD values for the Hanford Reach National Monument area, much of which, such as the (Fitzner Eberhardt) Arid Lands Ecology (Reserve), is very similar to the BC Controlled Area. It is very likely that these values will be applicable to the BC Controlled Area.

Table 5-1. 2002 Estimates of Hanford Site Background Concentrations (pCi/g) Based on Decay-Corrected Soil Surveillance Data.

	Am-241	Co-60	Cs-137	Eu-154	Eu-155	Pu-238	Pu-239/240	Sr-90	U-234*	U-235*	U-238*
Median	0.005	1.60E-04	0.255	-0.003	0.009	1.98E-04	0.008	0.075	0.762	0.033	0.733
Mean	0.011	0.001	0.301	-0.002	0.013	4.85E-04	0.009	0.106	0.793	0.052	0.763
Std. Dev.	0.016	0.004	0.251	0.016	0.017	0.001	0.008	0.163	--	--	--
Std. Error	0.004	0.001	0.039	0.003	0.003	1.48E-04	0.001	0.026	--	--	--
Minimum	-0.008	-0.006	0.019	-0.014	-0.007	-1.83E-04	3.47E-04	0.008	--	--	--
Maximum	0.062	0.023	1.005	0041	0.083	0.006	0.029	1.032	1.51	0.386	1.21
Count	16	41	41	36	36	41	41	41	--	--	--

*Taken from DOE/RL-96-12, 1996, *Hanford Site Background: Part 2, Soil Background for Radionuclides*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington, September.

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APPENDIX A
PERSONAL INTERVIEWS

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APPENDIX A
PERSONAL INTERVIEWS

Interview Notes

- Interviewee: John A. Winterhalder
- Date: May 2, 2003
- Topic: Stabilization of the BC Cribs and Trenches in the early 1980s.

Summary Notes from the Interview

John presently is the Environmental Compliance Officer for the Groundwater Protection Program. He wrote the plans for the operators who did the actual work of stabilization.

The stabilization work was conducted under the Radiation Area Reduction Program; W. F. (Bill) Heine was the program manager. The objective of the program was to reestablish control over some outdoor surface contamination areas that were largely out of control and expensive to maintain. Contamination was being spread through animals and vegetation, largely tumbleweeds. John said that there had been a period in the 1960s and 1970s that the cribs and trenches did not get the maintenance that they needed to control the contamination.

In the 1950s, large volumes of liquid waste exceeded the tank capacity, and, rather than build new tanks, the waste was dumped into the BC Cribs and Trenches, which were constructed for that purpose. The waste had high concentrations of radio-strontium and radio-cesium.

Some problems existed with the cribs, and the trenches were built to address this problem. The trenches themselves also had problems. Stories circulated regarding the exposure rate, which was, at times, said to be high enough to cause concerns about the exposure of the guards across the street at the 200 East Area gate. There also were stories that the liquid was highly hydrophobic and would not readily soak into the ground. When dirt was bulldozed into the trenches, the waste sometimes would just roll over and "slouch" the liquid out. It was a messy operation, but eventually the workers got the waste covered.

After the waste was covered, an animal or animals dug into the trench (or trenches) and spread the radioactivity over a large area.

During the stabilization in the early 1980s, a weighted piece of earth-moving equipment was run over the trenches and cribs to look for weak spots, but none were found. Cover soil was taken from the area just to the north (now designated 200-E-49). The entire area of the cribs and trenches was covered with about 2 ft of soil and then seeded with vegetation of a sort designed to resist tumbleweed growth. There also was some use of herbicide. John understands that this was one of the more successful replanting efforts. He believes the Biological Sciences group wrote some reports on this revegetation effort.

After the stabilization of the immediate area of the cribs and trenches, there was considerable discussion about what to do with the surrounding contaminated area (BC Controlled Area). There was discussion about stripping the land and then re-covering it with soil and plants. It was decided that this would not be a good idea, because the radionuclides in the BC Controlled Area (separate from the immediate area of the cribs and trenches) were not spreading. Thus, it was decided to leave the BC Controlled Area alone and work to control the source (the cribs and trenches themselves).

John does not know what happened to the aboveground piping used to fill the trenches.

John has no documents or photos left from this work.

John suggests that I interview W. L. (Bill) Osborne, who has a long history of the area, and W. M. (Bill) Hayward, who worked for Bill Heine.

John thinks of the "BC Cribs and Trenches" as being different from the "BC Controlled Area." According to John, the "Controlled Area" does not include the cribs and trenches, proper.

Interview Notes

- Interviewee: Al W. Conklin, Head, Air Emissions & Defense Waste Section, Division of Radiation Protection, Washington State Department of Health
- Date: June 10, 2003
- Topic: Radiological History of the BC Cribs Area
- Al was a senior scientist (environmental) for Rockwell Hanford from March 1981 to March 1986. During this time, he was involved in environmental surveillance of the BC Cribs and Trenches Area.

Summary Notes from the Interview

Use of BC Area firebreak roads as a contamination boundary: The firebreak roads were designed to be firebreaks and were not originally intended as contamination area boundaries. They later were adopted as convenient boundaries and did not necessarily contain all of the contaminated area.

Attempted cleanup in the southeastern corner of the firebreak roads after the 1984 range fire: A small area inside the southeastern corner of the firebreak roads—near the intersection of Dupont Avenue and Rockwell Street—burned in the 1984 range fire. W. F. (Bill) Heine, a Rockwell Hanford manager, decided to take the opportunity to remove the contaminated soil. The contaminated soil was removed using shovels and 5-gal buckets. After removing about 50 buckets of dirt, the workers gave up, because the activity was deep into the soil and seemed to be getting hotter as they went deeper. (NOTE: This is in contrast to airborne deposition, which tends to stay near the surface.) Al does not know the reason for this, but he speculated that it might be due to large amounts of animal urine. Al also noted that the area did not show up as very heavily contaminated in an aerial survey done in the 1980s. He speculated that this was because the contamination is largely strontium-90 and would not be detected by an aerial survey, because strontium-90 has no gamma emission. (NOTE: The presence of strontium-90 is consistent with contamination deep into the soil, because even in dry fallout strontium-90 will penetrate up to 20 cm into the soil in the area around the Hanford Site. Another study done at the Hanford Site of strontium-90-contaminated soil that was first irrigated for several years and then left dry for several years found strontium-90 at a depth of 43 cm.)

Survey of the area to the east of the firebreak roads (east of Dupont Avenue) in 1984: In 1984, after the range fire, some surveys were done east of Dupont Avenue (the easternmost firebreak road). Dense, spotty contamination (about 1 spot per 10 ft^2) was found in some areas and some contamination was found near the present soil contamination area boundary.

Cleanup of the heavily contaminated area near the cribs and trenches: Al believes that the soil well inside the firebreak roads near the BC Cribs and Trenches Area will have to be completely removed. He believes that the contamination is too heavy to be effectively removed by hand or with a large vacuum. Al speculated that the contamination outside the firebreak roads is spotty enough to allow removal of individual spots (perhaps with the Guzzler).

Hot tumbleweed contamination by Route 4 South to the north of the BC Cribs Area: In 1981, a large number of hot tumbleweeds were found north of the cribs and trenches by Route 4 South. Al wrote an occurrence report on this incident.

Buried pipe between Trenches B-29 and B-53A: Al said that the pipe used for the aboveground transport of waste to the trenches is buried between Trenches 216-B-29 and 216-B-53A and, as he recalls, a little north of a line between the two trenches. Al recalled that this source shows up as a hot spot on the airborne gamma surveys. (NOTE: This hot spot shows up clearly on the 1973 and 1978 aerial surveys.)

Buried equipment in the "Y" of the old road to the west of the BC Cribs, proper: Al said that there was some hot equipment buried in the "Y" of the old road to the west of the BC Cribs, proper. This is not the present "Y" to the northwest of the cribs, but a "Y" formed by two older roads, one of which ran parallel and just east of Trench 216-B-20 and one which ran just north of Trenches 210-B-20, -21, and -22. Al said that, to his knowledge, this buried equipment was never removed; he also mentioned that it showed up on some of the aerial surveys done. (NOTE: This hotspot shows up clearly on the 1973 and 1978 aerial surveys.)

Contamination of the area to the east of Trenches 216-B-23 to 216-B-28: Al mentioned that the area to the east of Trenches 216-B-23 through 216-B-28 is very contaminated.

Date of animal intrusion into Trench 216-B-28: Al believes that the date of the discovery of the animal intrusion into Trench 216-B-28 was before 1960. (NOTE: The record gives various dates, as early as 1958 and as late as 1960, for this event. Harold Maxfield [RHO-CD-673, *Handbook-200 Area Waste Sites*] gives the service dates for Trench 216-B-28 as April to June 1957.)

Previous posting of Route 4 South to the east of the BC Cribs Area: Al believes that the area on the eastern side of Route 4 South as far over as the road to the Central Landfill once was posted as a surface contamination area. (NOTE: These postings have been removed, and the soil contamination area now is bounded by a primitive road to the west of Route 4 South.)

Buried feed pipe to the BC Cribs and Trenches: Al mentioned that the buried waste feed pipe to the BC Cribs and Trenches leaked, that there is a lot of contamination along the pipeline, and that there used to be a problem with hot tumbleweeds growing over this pipeline.

Contaminated article dumped into the groundwater well between Trenches 216-B-52 and 216-B-23: Al recalled that a contaminated article had been dumped into a groundwater well pipe somewhere between Trenches 216-B-52 and 216-B-23.

Degree of animal contamination in the area of the BC Cribs and Trenches: Al said that workers found contaminated animals of every kind—rabbits, burrowing owls, sage rats, coyotes—in the BC Cribs Area. The degree of the contamination among animal life was very widespread.

Area below the band of sand dunes running east-west that bisect the present BC Controlled Area: Al said he never visited the southern part of the present BC soil contamination area (below the belt of sand dunes).

Interview Notes

- Interviewees: W. L. (Bill) Osborne, Fluor Hanford, Supervisor, Radiation Area Remediation; W. M. (Bill) Hayward, Bechtel Hanford, Inc. (BHI), Field Engineer, Radiological Area Remedial Action – 100 Areas; Chris Shannon, Fluor Hanford, Scientist, Radiation Area Remediation
- Date: May 21, 2003
- Topic: Activities associated with BC Cribs and Trenches and the BC Controlled Area

Summary Notes from the Interview

In 1996, the posted area was that within the fire roads plus a small amount outside the fire roads to the southwest. About early November 1996, surveys under the direction of Bill Osborne and Mike Dillon were done to the east of the posted area. Some spotty contamination was found and was reported in an occurrence report. Additional surveys then were done. In discussions with the U.S. Department of Energy, it was determined that the workers had to post and control each area individually or expand the area. To prevent having to control many small areas, it was decided to move the boundaries to the present soil contamination area boundaries. This expansion took place in late 1996 or early 1997. There has been no movement of the boundaries since then. Some special consideration was given to posting, because to fully meet the posting requirements was estimated to cost $445,000 (mostly labor costs over such a large area).

RL-BHI-DND-1996-0023, Final Report, *Legacy Contamination Discovered Outside a Radiologically Controlled Area*, provides a description of activities leading up to posting the large soil contamination area. BHI-01225, *Sampling and Analysis Instruction for the 200 B/C Controlled Area Reposting*, provides additional information.

In 1982, a range fire burned a small portion of the southeast corner of the area within the fire roads. After the fire, there was an effort to decontaminate the area. Large amounts of contaminated soil were found, and the effort was abandoned.

Bill Hayward said that he had some years ago prepared an estimate of the cost to clean up the contaminated area. The estimate ran into the hundreds of millions of dollars.

Bill Hayward noted that there was, at one time, a plan to use the lower part of the present BC Controlled Area as a site for an expansion of the Environmental Restoration Disposal Facility.

There was, at one time, at a location below the fire road area, a line of steel towers with air sampling heads on each at several heights. There is speculation that this was used by someone to perform airborne dispersion studies, and that this might have been done with radioactive material. It probably was done before 1975.

Somewhere south of the fire road area is a building that is sliding into a hole; the building is setting at an angle on the edge of the hole.

An old Army communications area was set up to the east of the fire road area.

None of the three interviewed knew of any dumping or of any disposal of radioactive material south of the band of sand dunes running across the middle of the big BC Controlled Area.

Bill Hayward and Bill Osborne said they knew of no other sources of potential contamination for the lower part of the BC Controlled Area (south of the band of sand dunes) other than airborne from the 200 Areas and occasional animal droppings and tumbleweed specks.

Bill Osborne offered his BC Controlled Area files for review.

Interview Notes

- Interviewees: David Ellingson, David Phipps, Keith Yates
- Date: July 23, 2003
- Topic: Biological Contamination and the Degree of Transferability

David Ellingson formerly was a radiological field operations supervisor with 10 years of experience in outdoor radiation monitoring and biological control.

David Phipps has, since 1992, been a lead radiological control technician working with outdoor contamination. He works for Near-Field Environmental Monitoring Radiological Control.

Keith Yates is a radiological control technician with experience in the BC Area.

Summary Notes from the Interview

In summary, contamination in the soil only transfers to shoes or other surfaces if the soil or biological material in which the contamination exists actually sticks to the surface. For instance, dry, sandy soil that does not stick to shoes does not result in transferable contamination. However, if the soil is wet and muddy and the mud sticks to the shoes and there is contamination in the mud, the contamination will be on the shoes.

Of the mobile plants, tumbleweed and tumble mustard, only tumbleweed is found contaminated. Tumble mustard is not found to be contaminated. (Rabbit brush also is prone to be contaminated, but it is not mobile.) Tumbleweed contamination can take the form of an entire plant, a branch, a pile of bits, a seed, or a small fragment. Dry tumbleweed will not transfer directly (only if the soil itself clings to a surface). Green tumbleweed sap can be contaminated.

Concerning the movement of contaminated tumbleweed from the BC Cribs and Trenches, it generally was believed that the thick stand of sagebrush surrounding the BC Cribs and Trenches (within the firebreaks) would effectively stop almost all tumbleweed from leaving this area. Last year, an extensive survey was conducted at the Central Landfill, at the edge of the BC Controlled Area, and no hot tumbleweed was found. It was mentioned that Ray Johnson has looked at the normal range of tumbleweed.

Concerning animal contamination, it was estimated that a coyote urine spot might be 8 to 12 in. in diameter and 6 to 8 in. deep in the sand. At one time, coyote urine spots would be found on telephone poles, garbage cans, and sagebrush stumps. Concerning scat, it was noted that the last hot coyote scat that anyone could remember was in 1995. No one present could recall any hot scat being found on Army Loop Road. Generally, because the ponds and ditches have dried up, workers have found few hot animals.

The probable nature of biological contamination in the Southern BC Area below the dunes was discussed. It generally was believed that any contamination found in that area would be spots and easy to remove.

It was mentioned that a transferability study had been done by BHI. It was mentioned that the former BHI biological control person, Chris Kemp, now with CH2M HILL Hanford Group, Inc., might have some documented evidence that radioactive tracers were used in dispersion studies in the BC Area. W. Joel Millsap mentioned that the reports that he had read mentioned only the use of existing ground contamination to study resuspension and airborne transport.

Curtis Eggemeyer, now on leave and expected back around the first of September 2003, has performed a lot of health physics work in the BC Cribs Area.

There was some discussion over the posting of the large BC Area, which apparently has been a source of confusion. Joel Millsap related that, while doing the history review, he had read of posting problems going back for decades; they seem to arise periodically. Apparently, the posting of such areas often has been a source of confusion.

Interview Notes

- Interviewees: Mike Dillon and Barry Headley
- Date: September 8, 2003
- Topic: Radiological History of the BC Cribs Area

Mike Dillon worked as an analyst with duties concerning the BC Area, as well as other areas, from 1995 to 1997. From 1999 to 2001, he was the Radiation Control Supervisor for the Technical Support group for BHI and worked at the BC Area.

Barry Headley was a health physics technician for the Technical Support group from 1991 to 2001. He performed many surveys in the BC Area, including roads, trenches, land surveys, and transect surveys.

Summary Notes from the Interview

General transferability of contamination onto people and equipment: Barry said that in his years performing work in the BC Area he never found any contamination on people and equipment coming out of the contaminated area. The contamination does not stick.

Transect surveys: The background count rate on the instruments used in the 1999 transect survey was 450 counts per minute (cpm). However, based on the survey needs, only count rates in excess of 2,000 cpm are shown on the survey map. Thus, the original file, if plotted, likely would show more radiation structure to the area. The transect survey was done with 2- by 2-in. sodium iodide detectors held about 6 in. off the ground with the surveyor walking at about 12 to 18 in/s.

Transferability surveys during the re-posting study: Barry did the actual transferability study fieldwork. He walked through a 3 m circle eight times, dragging his feet (as if he were very tired) as he went; he wore boots with lugged, Vibram[1] soles. After walking through the area, his boots were surveyed for contamination. If contamination was found, that ended the work at that spot. If no contamination was found, the workers poured 10 gal of water on the ground and he repeated the walk-through procedure. The boots again were examined for contamination. Barry said that if dry contamination was found, it could be removed by tapping the boots together.

Surveys done along Army Loop Road: Annual surveys of the perimeter roads, including Army Loop Road, have been done for some years, at least since before 1995. These are done with the mobile surface contamination monitor (MSCM-II) (tractor) at about 2 mi/h. The MSCM-II uses large-area plastic scintillators. In the late 1990s, at about the time that the transect survey was done, some additional surveys along Army Loop Road were done. One survey with the tractor, done in a broad serpentine pattern, paralleled Army Loop Road from the Central Landfill to the intersection of Isochem Avenue and Army Loop Road and about 50 ft north of Army Loop Road; this survey found a small number, perhaps two, spots of contamination.

Another survey was done just to the south of Army Loop Road and ran from the intersection of Telephone Line Road and Army Loop Road to the 200 West Area near the Rattlesnake Gate.

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[1]Vibram is a trademark of VIBRAM S.p.A.

A string of 100-ft^2 areas spaced at about 200 ft were manually surveyed with beta-gamma instruments. No contamination was found in any of these areas.

Other Potential Contacts for Information Related to BC Area:

Mitch Kobierowski (509-521-4224) was Barry Headley's lead technician during the period that the BC Area surveys were being done in the late 1990s.

Wendy Thompson (509-372-9597) of the BHI Environmental Compliance group may have some of the old surveys.

The supervisor of the BHI Technical Support group before Dillon was Jim Parsons (509-372-3927).

Conan Wade (509-373-1735) worked with Jim Parsons in the BC Area.

Finding Past Surveys:

Finding past radiological surveys has been complicated by organizational changes. One approach to finding past BHI surveys is to get a copy of the survey logs for the surveys beginning with the strings ERSR-TS-, RSR-TS-, ERSR-FRM-, and RSR-TS-. From the logs, one can read the descriptions and get the survey numbers; with the survey numbers, the surveys can be obtained. Some survey information is available on an existing share drive. A contact at BHI's Document Information Service is Barbara Slade at 509-372-9727.

Air sampling towers and the potential for an intentional release: The presence of the air sampling towers and the potential for an intentional release of activity for dispersion studies some time in the past was discussed. Barry said that the vegetation at the area of highest contamination just south of ARCHO Street is unlike anything else in the area and this, combined with the air sampling towers, has led people to speculate that some sort of intentional release took place in the past. There is no known documentation for this.

Interview Notes

- Interviewee: Curtis Eggemeyer, Health Physics Technician, Fluor Hanford
- Date: December 2, 2003
- Topic: Radiological Information about the BC Cribs Area

Curtis is a health physics technician (environmental) for Fluor Hanford. He also worked for BHI as an environmental health physics technician. Curtis has about 8 years of experience at the Hanford Site doing environmental health physics work, and he has considerable experience working around the BC Cribs and Trenches.

Summary Notes from the Interview

Curtis noted that, in his experience, characterization and remediation work of the type being envisioned for the BC Controlled Area is greatly facilitated by Global Positioning System (GPS) radiological survey methods. This allows the radiological information to be quickly acquired and displayed for work planning.

Fluor Hanford presently does not have manually used radiation detection equipment with a GPS capability. These instruments remained with BHI when the work was transitioned to Fluor Hanford.

Presently, two tractors are fitted with detectors and GPS equipment. One tractor has four detectors, one has three, and both are referred to as MSCM-II. Both are operational now.

A potential problem exists with the availability of heath physics technician support in operating the rad tractors and other such equipment. Originally, three technicians were doing this type of work, but now, because of staff cutbacks, there is only one.

Curtis suggested that a pilot area be excavated first in order to test the needed systems, before major excavation is undertaken.

Curtis mentioned that blowing sand is obscuring the beta radiation and that, for this reason, discovery surveys are best conducted with gamma detectors.

Curtis never has surveyed beyond the present western boundary of the BC Controlled Area.

Curtis does not recall ever finding any contamination on Army Loop Road, and he does not recall ever finding transferable contamination while working on the BC firebreak roads.

Curtis said that a few years back, probably in 1999, he found two hot spots on the BC Controlled Area boundary to the east of Dupont Avenue. He believed that they probably were urine spots. He said the workers tried to dig them up, but they seemed to get more active as they dug down. The spots also seemed to spread out more as the workers dug deeper. The total depth was 2 ft or more.

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APPENDIX B
LIST OF PHOTOGRAPHS OF THE BC AREA

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APPENDIX B

LIST OF PHOTOGRAPHS OF THE BC AREA

In the course of this review, the following photographs of the BC Area were found and are listed for reference. In some cases, scans were only produced and in other cases, both scans and prints were produced; this is noted. All prints and scans were obtained through the Lockheed Martin Information Technology Photography group.

Negative Number	Date	Format	View
3380	Early 1950s	Print and scan	Construction of BC Cribs
3482-neg	1955	Print and scan	BC Cribs newly finished
3807-neg	1956	Print and scan	Construction of lower trenches
3943-neg	1957	Print and scan	Detail of trench construction
40599-35cn	--	Print and scan	BC Trenches from the south; shows asphalt pad
40599-36cn	--	Print and scan	BC Trenches from the southeast; shows asphalt pad
42111-6cn	1966	Print and scan	BC Area from the north
49755	1969	Print and scan	Straight down on BC Cribs and Trenches
62440	1973	Print and scan	BC Cribs and Trenches from the east
91020-28cn	1980	Print and scan	Straight down on BC Cribs
91020-21cn, 22cn, 27cn, and 28cn (4 images)	May 1980	Scan	--
8104484-7cn through 22cn (14 images)	June 1981	Scan	--
8105972-7cn through 22cn (14 images)	August 1981	Scan	--
8106185-1cn through 37cn (37 images)	August 1981	Scan	--
8108908-1cn through 4cn; 14 cn through 21cn; 25 through 30 cn (18 images)	October 1981	Scan	--
8203418-10cn through 30cn (21 images)	May 1982	Scan	--
103525-1cn and 2cn	September 1982	Scan	--
107262-2cn, 3cn, 7cn, and 8cn	April 1983	Scan	--
107851-17cn through 25cn; 29cn through 33cn (14 images)	May 1983	Scan	--
104264	1989	Print and scan	Straight down on BC Cribs and Trenches
107262-7cn	--	Print and scan	BC Cribs and Trenches from the northeast
8703594-80cn	1987	Print and scan	BC Cribs and Trenches from the northeast; shows commercial burial ground
00060196	June 2000	Scan	Aerial of fire damage

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APPENDIX C

INFORMATION ON BIOTA SAMPLES IN THE BC AREA

Disclaimer: The information provided in this appendix is from the Near-Facility Monitoring Biotic Database (NFMBD), maintained by the Environmental Monitoring and Investigations (EM&I) group, Duratek Federal Services, Inc., Northwest Operations. The NFMBD contains selected monitoring information and analytical data for investigations conducted by EM&I and Pacific Northwest National Laboratory personnel since 1965 and is updated as funds become available. The information in this appendix primarily applies to the 200 Areas and does not represent the Hanford Site as a whole.

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Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/79	RHO-CD-867		Cs-137	100 mrad/h				216-B-19	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Pu-239	100 mrad/h				216-B-19	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Sr-90	100 mrad/h				216-B-19	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Uranium	100 mrad/h				216-B-19	Tumbleweed	Salsola sp.
01/01/80	81d	pellet	Cs-137	100,000 cpm		520,000	pCi/g	216-BC	Bird	Aves
01/01/80	81d	pellet	Pu-239	100,000 cpm				216-BC	Bird	Aves
01/01/80	81d	pellet	Sr-90	100,000 cpm		2,200,000	pCi/g	216-BC	Bird	Aves
01/01/80	81d	pellet	Uranium	100,000 cpm				216-BC	Bird	Aves
01/01/90	WHC-EP-0145-4		Cs-137	20,000 cpm				216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Pu-239	20,000 cpm				216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Sr-90	20,000 cpm		5,800	pCi/g	216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Uranium	20,000 cpm				216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Cs-137	20,000 cpm		120	pCi/g	216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Pu-239	20,000 cpm				216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Sr-90	20,000 cpm		860	pCi/g	216-BC	Western Termite	Isoptera
01/01/90	WHC-EP-0145-4		Uranium	20,000 cpm				216-BC	Western Termite	Isoptera
01/01/77	PNL-2614		Cs-137		<det			216-BC	Mouse	Muridae
01/01/77	PNL-2614		Sr-90			1.2	pCi/g	216-BC	Mouse	Muridae
01/01/77	PNL-2614		Cs-137		<det			216-BC	Deer Mouse	Peromyscus maniculates
01/01/77	PNL-2614		Pu-239		<det			216-BC	Deer Mouse	Peromyscus maniculates
01/01/77	PNL-2614		Sr-90			0.05	pCi/g	216-BC	Deer Mouse	Peromyscus maniculates
01/01/78	RHO-CD-968		Cs-137		<det			216-BC	Mouse	Muridae
01/01/78	RHO-CD-968		Pu-239			0.005	pCi/g	216-BC	Mouse	Muridae
01/01/78	RHO-CD-968		Sr-90			0.29	pCi/g	216-BC	Mouse	Muridae
01/01/78	RHO-CD-968		Cs-137		<det			216-BC	Mouse	Muridae
01/01/78	RHO-CD-968		Pu-239			0.006	pCi/g	216-BC	Mouse	Muridae
01/01/78	RHO-CD-968		Sr-90			3.5	pCi/g	216-BC	Mouse	Muridae
01/01/74	BNWL-B-336		Cs-137			5.5	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Sr-90			220	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Cs-137			1.9	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Sr-90			220	pCi/g	216-BC	Rabbit	Leporidae

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/74	BNWL-B-336		Cs-137			2	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Sr-90			78	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Pu-239		<det			216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Sr-90			0.47	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Cs-137			0.48	pCi/g	216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Pu-239		<det			216-BC	Rabbit	Leporidae
01/01/74	BNWL-B-336		Sr-90			0.14	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Cs-137			0.09	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Pu-239			0.0004	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Sr-90			76	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Cs-137				pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Pu-239			0.002	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Sr-90			76	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Cs-137			0.009	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Pu-239			0.002	pCi/g	216-BC	Rabbit	Leporidae
01/01/76	BNWL-2089		Sr-90			19	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Pu-239			0.002	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Sr-90			24	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Pu-239			0.0002	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Sr-90			27	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Cs-137			0.46	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Pu-239			0.01	pCi/g	216-BC	Rabbit	Leporidae
01/01/77	PNL-2614		Sr-90			170	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Pu-239			0.009	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Sr-90			6.9	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Cs-137			0.65	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Pu-239		<det			216-BC	Rabbit	Leporidae
01/01/78	RHO-CD-968		Sr-90			0.07	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-LD-132		Cs-137			0.04	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-LD-132		Sr-90			5.4	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-LD-132		Cs-137			3	pCi/g	216-BC	Rabbit	Leporidae

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/79	RHO-LD-132		Sr-90			7.8	pCi/g	216-BC	Rabbit	Leporidae
01/01/80	PNL-3357		Cs-137			0.05	pCi/g	216-BC	Rabbit	Leporidae
01/01/80	PNL-3357		Sr-90			2.7	pCi/g	216-BC	Rabbit	Leporidae
01/01/81	PNL-4211		Cs-137			0.03	pCi/g	216-BC	Rabbit	Leporidae
01/01/81	PNL-4211		Sr-90			3.2	pCi/g	216-BC	Rabbit	Leporidae
01/01/82	RHO-HS-SR-83-13 1 P		Cs-137			0.03	pCi/g	216-BC	Rabbit	Leporidae
01/01/82	RHO-HS-SR-83-13 1 P		Sr-90			0.24	pCi/g	216-BC	Rabbit	Leporidae
01/01/83	PNL-SA-11401		Cs-137			0.33	pCi/g	216-BC	Rabbit	Leporidae
01/01/83	PNL-SA-11401		Sr-90			120	pCi/g	216-BC	Rabbit	Leporidae
01/01/83	PNL-SA-11401		Cs-137			0.03	pCi/g	216-BC	Rabbit	Leporidae
01/01/83	PNL-SA-11401		Sr-90			0.97	pCi/g	216-BC	Rabbit	Leporidae
01/01/87	WHC-EP-0161		Cs-137			0.067	pCi/g	216-BC	Rabbit	Leporidae
01/01/87	WHC-EP-0161		Sr-90			40	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0161		Cs-137			0.0068	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Pu-239			0.00087	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Sr-90			8.1	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Cs-137			0.25	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Pu-239			0.00044	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Sr-90			49	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Cs-137			0.047	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Pu-239			0.00094	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Sr-90			31	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Cs-137			0.0035	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Pu-239			0.000071	pCi/g	216-BC	Rabbit	Leporidae
01/01/91	WHC-EP-0601		Sr-90			11	pCi/g	216-BC	Rabbit	Leporidae
01/01/84	RHO-HS-SR-84-13P	urine	Cs-137	100,000 cpm				216-BC	Animal	Animalia
01/01/84	RHO-HS-SR-84-13P	urine	Pu-239	100,000 cpm				216-BC	Animal	Animalia
01/01/84	RHO-HS-SR-84-13P	urine	Sr-90	100,000 cpm				216-BC	Animal	Animalia
01/01/84	RHO-HS-SR-84-13P	urine	Uranium	100,000 cpm				216-BC	Animal	Animalia
01/01/76	ARH-LD-154		Cs-137			39	pCi/g	216-BC	Balsamroot	Balsamorhiza sp.
01/01/76	ARH-LD-154		Sr-90			100	pCi/g	216-BC	Balsamroot	Balsamorhiza sp.
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Sagebrush	Artemisia tridenta
01/01/75	BNWL-1979		Sr-90			30	pCi/g	216-BC	Sagebrush	Artemisia tridenta
01/01/76	ARH-LD-154		Cs-137			72	pCi/g	216-BC	Sagebrush	Artemisia tridenta
01/01/76	ARH-LD-154		Sr-90			370	pCi/g	216-BC	Big Sagebrush	Artemisia tridenta

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Cheatgrass	Bromus tectorum
01/01/75	BNWL-1979		Sr-90			68	pCi/g	216-BC	Cheatgrass	Bromus tectorum
01/01/76	ARH-LD-154		Cs-137			23,000	pCi/g	216-BC	Cheatgrass	Bromus tectorum
01/01/76	ARH-LD-154		Sr-90			67,000	pCi/g	216-BC	Cheatgrass	Bromus tectorum
01/01/75	BNWL-1979		Cs-137			6	pCi/g	216-BC	Desertparsley	Lomatium sp.
01/01/75	BNWL-1979		Sr-90			26	pCi/g	216-BC	Desertparsley	Lomatium sp.
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Desertparsley	Lomatium sp.
01/01/75	BNWL-1979		Sr-90			32	pCi/g	216-BC	Desertparsley	Lomatium sp.
01/01/76	ARH-LD-154		Cs-137			150	pCi/g	216-BC	Desertparsley	Lomatium sp.
01/01/76	ARH-LD-154		Sr-90			80	pCi/g	216-BC	Desertparsley	Lomatium sp.
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Fiddleneck	Amsinckia
01/01/75	BNWL-1979		Sr-90			70	pCi/g	216-BC	Fiddleneck	Amsinckia
01/01/73	BNWL-1910		Cs-137			4	pCi/g	216-BC	Mustard	Capparales
01/01/73	BNWL-1910		Sr-90			1,300	pCi/g	216-BC	Mustard	Capparales
01/01/75	BNWL-1979		Cs-137			4	pCi/g	216-BC	Mustard	Capparales
01/01/75	BNWL-1979		Sr-90			1,300	pCi/g	216-BC	Mustard	Capparales
01/01/76	ARH-LD-154		Cs-137			6,400	pCi/g	216-BC	Mustard	Capparales
01/01/76	ARH-LD-154		Sr-90			11,000	pCi/g	216-BC	Mustard	Capparales
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Douglas Rabbitbrush	Chrysothamnus sp.
01/01/75	BNWL-1979		Sr-90			24	pCi/g	216-BC	Rabbitbrush	Chrysothamnus sp.
01/01/76	ARH-LD-154		Cs-137			6	pCi/g	216-BC	Rabbitbrush	Chrysothamnus sp.
01/01/76	ARH-LD-154		Sr-90			48	pCi/g	216-BC	Rabbitbrush	Chrysothamnus sp.
01/01/76	ARH-LD-154		Cs-137			500	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/76	ARH-LD-154		Sr-90			1,100	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Cs-137	60,000 cpm (multiple)				216-BC	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Pu-239	60,000 cpm (multiple)				216-BC	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Sr-90	60,000 cpm (multiple)				216-BC	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Uranium	60,000 cpm (multiple)				216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Cs-137		<det			216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Sr-90			1,100,000	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Cs-137		<det			216-BC	Russian Thistle	Salsola sp.

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Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/81	PNL-3729		Sr-90			800,000	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Cs-137			20	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Sr-90			18,000	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Cs-137			25	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Sr-90			140,000	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Cs-137		<det			216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Sr-90			3,200,000	pCi/g	216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Cs-137		<det			216-BC	Tumbleweed	Salsola sp.
01/01/81	PNL-3729		Sr-90			150,000	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Cs-137			720	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Sr-90			130,000	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Cs-137			210	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/81	PNL-3729		Sr-90			90,000	pCi/g	216-BC	Russian Thistle	Salsola sp.
01/01/76	ARH-LD-154		Cs-137			35	pCi/g	216-BC	Sandbur	Cenchrus
01/01/76	ARH-LD-154		Sr-90			4,600	pCi/g	216-BC	Sandbur	Cenchrus
01/01/75	BNWL-1979		Cs-137			2	pCi/g	216-BC	Scurfpea	Fabaceae
01/01/75	BNWL-1979		Sr-90			36	pCi/g	216-BC	Scurfpea	Fabaceae
01/01/76	ARH-LD-154		Cs-137			700	pCi/g	216-BC	Scurfpea	Fabaceae
01/01/76	ARH-LD-154		Sr-90			820	pCi/g	216-BC	Scurfpea	Fabaceae
01/01/75	BNWL-1979		Cs-137			9	pCi/g	216-BC	Spiny Hopsage	Grayia spinosa
01/01/75	BNWL-1979		Sr-90			46	pCi/g	216-BC	Spiny Hopsage	Grayia spinosa
01/01/75	BNWL-1979		Cs-137		<det			216-BC	Spiny Hopsage	Grayia spinosa
01/01/75	BNWL-1979		Sr-90			21	pCi/g	216-BC	Spiny Hopsage	Grayia spinosa
01/01/76	ARH-LD-154		Cs-137			62	pCi/g	216-BC	Spiny Hopsage	Grayia spinosa
01/01/76	ARH-LD-154		Sr-90			100	pCi/g	216-BC	Spiny Hopsage	Grayia spinosa
01/01/78	RHO-LD-132	feces	Cs-137			4.9	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.7		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/79	RHO-CD-867		Cs-137	1,000 cpm – 10,000 cpm (multiple)				216-BC-35 -42	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Pu-239	1,000 cpm – 10,000 cpm (multiple)				216-BC-35 -42	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Sr-90	1,000 cpm – 10,000 cpm (multiple)				216-BC-35 -42	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Uranium	1,000 cpm – 10,000 cpm (multiple)				216-BC-35 -42	Tumbleweed	Salsola sp.

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/79	RHO-CD-867		Cs-137	1,000 cpm – 20,000 cpm (multiple)				216-BC-53 -58	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Pu-239	1,000 cpm – 20,000 cpm (multiple)				216-BC-53 -58	Russian Thistle	Salsola sp.
01/01/79	RHO-CD-867		Sr-90	1,000 cpm – 20,000 cpm (multiple)				216-BC-53 -58	Tumbleweed	Salsola sp.
01/01/79	RHO-CD-867		Uranium	1,000 cpm – 20,000 cpm (multiple)				216-BC-53 -58	Tumbleweed	Salsola sp.
01/01/91	WHC-EP-0601		Cs-137	<det		2.2	pCi/g	216-BC	Cliff Swallow	Hirundo pyrrhonota
01/01/91	WHC-EP-0601		Pu-239	<det		0.38	pCi/g	216-BC	Cliff Swallow	Hirundo pyrrhonota
01/01/91	WHC-EP-0601		Sr-90	<det		0.64	pCi/g	216-BC	Cliff Swallow	Hirundo pyrrhonota
01/01/91	WHC-EP-0601		Uranium	<det		0.012	pCi/g	216-BC	Cliff Swallow	Hirundo pyrrhonota
01/01/79	RHO-CD-867	feces	Cs-137			2	pCi/g	216-BC	Coyote	Canis latrans
01/01/79	RHO-CD-867	feces	Pu-239		<det			216-BC	Coyote	Canis latrans
01/01/79	RHO-CD-867	feces	Sr-90			2.1	pCi/g	216-BC	Coyote	Canis latrans
01/01/78	RHO-LD-132	feces	Cs-137			2.9	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	feces	Pu-239			0.02	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	feces	Sr-90			18	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Cs-137			1.1	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Pu-239		<det			216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Sr-90			6	pCi/g	216-BC	Rabbit	Leporidae
01/01/81	PNL-3729	feces	Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/82	PNL-4657	feces	Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/83	PNL-5038	feces	Cs-137			0.65	pCi/g	216-BC	Rabbit	Leporidae
01/01/80	81d		Cs-137		<det			216-BC	Cheatgrass	*Bromus tectorum*
01/01/79	RHO-CD-867	Terrestrial Composite	Sr-90			1.6		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/79	RHO-CD-867	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/81	PNL-3729	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/82	PNL-4657	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/83	PNL-5038	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/84	RHO-HS-SR-84-13P	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Cs-137			0.069		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Pu-239		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Sr-90		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/88	PNL-6825	Terrestrial Composite	Cs-137			0.13		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/88	PNL-6825	Terrestrial Composite	Sr-90			0.18		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			2.1	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.41		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137		<det			216-BC	Coyote	Canis latrans
01/01/78	RHO-LD-132	feces	Pu-239			0.07	pCi/g	216-BC	Coyote	Canis latrans
01/01/78	RHO-LD-132	feces	Sr-90			5.1	pCi/g	216-BC	Coyote	Canis latrans
01/01/78	RHO-LD-132	feces	Cs-137			4.2	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	feces	Pu-239			0.01	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	feces	Sr-90			3.8	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Cs-137			1.6	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Pu-239			0.02	pCi/g	216-BC	Rabbit	Leporidae
01/01/79	RHO-CD-867	feces	Sr-90			4.4	pCi/g	216-BC	Rabbit	Leporidae
01/01/81	PNL-3729	feces	Cs-137			0.65	pCi/g	216-BC	Rabbit	Leporidae
01/01/82	PNL-4657	feces	Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/83	PNL-5038	feces	Cs-137		<det			216-BC	Rabbit	Leporidae
01/01/80	81d		Cs-137		<det			216-BC	Sagebrush	Artemisia tridenta
01/01/80	81d		Cs-137		<det			216-BC	Cheatgrass	Bromus tectorum
01/01/79	RHO-CD-867	Terrestrial Composite	Cs-137			0.1		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/79	RHO-CD-867	Terrestrial Composite	Sr-90			1.2		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/79	RHO-CD-867	Terrestrial Composite	Pu-239		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/81	PNL-3729	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/82	PNL-4657	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/83	PNL-5038	Terrestrial Composite	Cs-137		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/84	RHO-HS-SR-84-13P	Terrestrial Composite	Cs-137			0.082		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Cs-137			0.12		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Pu-239		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/85	RHO-HS-SR-85-13P	Terrestrial Composite	Sr-90		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/86	UNI-4065	Terrestrial Composite	Cs-137			0.66		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/86	UNI-4065	Terrestrial Composite	Pu-239		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/86	UNI-4065	Terrestrial Composite	Sr-90		<det			216-BC	Terrestrial Composite	Terrestrial Composite
01/01/87	PNL-6464	Terrestrial Composite	Cs-137			0.26		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/88	PNL-6825	Terrestrial Composite	Cs-137			0.075		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Sr-90			0.14		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Uranium			0.05		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Pu-239			0.005		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Cs-137			0.52		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Uranium			0.025		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Cs-137			0.31		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Sr-90			0.092		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Pu-239			0.00093		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Pu-239			0.00049		216-BC	Terrestrial Composite	Terrestrial Composite

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/92	93b	Terrestrial Composite	Cs-137			0.069		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Cs-137			0.12		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Uranium			0.17		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Pu-239			0.0018		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Sr-90			0.79		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Cs-137			0.13		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Uranium			0.026		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Sr-90			4.1		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Pu-239			0.00046		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Pu-239			0.0025		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Cs-137			0.036		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			3	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.74		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			7.9	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			1.2		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.38		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.24		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Uranium			0.014		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Pu-239			0.002		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Sr-90			0.049		216-BC	Terrestrial Composite	Terrestrial Composite

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Cs-137			0.0088		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Cs-137			0.014		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Uranium			0.031		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Pu-239			0.00044		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Sr-90			0.008		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Cs-137			0.019		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Pu-239			0.00053		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			9.7	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			2.3		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			0.21	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	feces	Cs-137			0.57	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.29		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			1	pCi/g	216-BC	Rabbit	Leporidae
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Sr-90			0.18		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Uranium			0.038		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Cs-137			0.072		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/90	WHC-EP-0145-4	Terrestrial Composite	Pu-239			0.00085		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Cs-137			0.037		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Uranium			0.005		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Pu-239			0.00079		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/91	WHC-EP-0601	Terrestrial Composite	Sr-90			0.085		216-BC	Terrestrial Composite	Terrestrial Composite

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
01/01/92	93b	Terrestrial Composite	Cs-137			0.022		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/92	93b	Terrestrial Composite	Pu-239			0.00034		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			0.51	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.75		216-BC	Terrestrial Composite	Terrestrial Composite
01/01/78	RHO-LD-132	feces	Cs-137			1.2	pCi/g	216-BC	Rabbit	Leporidae
01/01/78	RHO-LD-132	Terrestrial Composite	Cs-137			0.25		216-BC	Terrestrial Composite	Terrestrial Composite
05/19/95	ERS 1996 (Fluor Database)		Co-60			-0.01	pCi/g	BC Controlled Area	Soil	Soil
05/19/95	ERS 1996 (Fluor Database)		Cs-137			0.044	pCi/g	BC Controlled Area	Soil	Soil
05/19/95	ERS 1996 (Fluor Database)		Pu-239/40			0.0017	pCi/g	BC Controlled Area	Soil	Soil
05/19/95	ERS 1996 (Fluor Database)		Sr-90			0.061	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Co-60			0.00088	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Cs-137			0.066	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Pu-239/40			0.0033	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Sr-90			0.44	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Co-60			0.0043	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Cs-137			0.029	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Pu-239/40		<	0.0054	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Sr-90			0.075	pCi/g	BC Controlled Area	Soil	Soil
05/18/95	ERS 1996 (Fluor Database)		Co-60			0.013	pCi/g	BC Controlled Area	Soil	Soil
05/18/95	ERS 1996 (Fluor Database)		Cs-137			0.12	pCi/g	BC Controlled Area	Soil	Soil

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Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
05/18/95	ERS 1996 (Fluor Database)		Pu-239/40			0.0027	pCi/g	BC Controlled Area	Soil	Soil
05/18/95	ERS 1996 (Fluor Database)		Sr-90			0.16	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Co-60			0.00097	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Cs-137			0.046	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Pu-239/40			0.0071	pCi/g	BC Controlled Area	Soil	Soil
05/19/97	ERS 1998 (Fluor Database)		Sr-90			0.91	pCi/g	BC Controlled Area	Soil	Soil
05/28/97	ERS 1998 (Fluor Database)		Co-60			-0.0015	pCi/g	BC Controlled Area	Soil	Soil
05/28/97	ERS 1998 (Fluor Database)		Cs-137			0.24	pCi/g	BC Controlled Area	Soil	Soil
05/28/97	ERS 1998 (Fluor Database)		Pu-239/40			0.0067	pCi/g	BC Controlled Area	Soil	Soil
05/28/97	ERS 1998 (Fluor Database)		Sr-90			0.67	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Co-60			0.00024	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Cs-137			0.013	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Pu-239/40			0.0016	pCi/g	BC Controlled Area	Soil	Soil
05/24/99	ERS-1999 (Fluor Database)		Sr-90			-0.061	pCi/g	BC Controlled Area	Soil	Soil
05/27/94	ERS 1995 (Fluor Database)		Co-60			0.046	pCi/g	BC Controlled Area	Plant	Plantae
05/27/94	ERS 1995 (Fluor Database)		Cs-137			-0.0041	pCi/g	BC Controlled Area	Vegetation	Plantae
05/27/94	ERS 1995 (Fluor Database)		Pu-239/40			0.0034	pCi/g	BC Controlled Area	Vegetation	Plantae
05/27/94	ERS 1995 (Fluor Database)		Sr-90			0.28	pCi/g	BC Controlled Area	Vegetation	Plantae
05/19/95	ERS 1996 (Fluor Database)		Co-60			-0.013	pCi/g	BC Controlled Area	Plant	Plantae

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
05/19/95	ERS 1996 (Fluor Database)		Cs-137			0.024	pCi/g	BC Controlled Area	Plant	Plantae
05/19/95	ERS 1996 (Fluor Database)		Pu-239/40			0.00043	pCi/g	BC Controlled Area	Plant	Plantae
05/19/95	ERS 1996 (Fluor Database)		Sr-90			1	pCi/g	BC Controlled Area	Plant	Plantae
05/19/97	ERS 1998 (Fluor Database)		Co-60			-0.013	pCi/g	BC Controlled Area	Plant	Plantae
05/19/97	ERS 1998 (Fluor Database)		Cs-137			0.0034	pCi/g	BC Controlled Area	Vegetation	Plantae
05/19/97	ERS 1998 (Fluor Database)		Pu-239/40			0.0011	pCi/g	BC Controlled Area	Plant	Plantae
05/19/97	ERS 1998 (Fluor Database)		Sr-90			-0.11	pCi/g	BC Controlled Area	Vegetation	Plantae
05/24/99	ERS-1999 (Fluor Database)		Co-60			0.0017	pCi/g	BC Controlled Area	Plant	Plantae
05/24/99	ERS-1999 (Fluor Database)		Cs-137			-0.0036	pCi/g	BC Controlled Area	Vegetation	Plantae
05/24/99	ERS-1999 (Fluor Database)		Pu-239/40			0.0019	pCi/g	BC Controlled Area	Vegetation	Plantae
05/24/99	ERS-1999 (Fluor Database)		Sr-90			0.37	pCi/g	BC Controlled Area	Vegetation	Plantae
05/27/94	ERS 1995 (Fluor Database)		Co-60			0.019	pCi/g	BC Controlled Area	Plant	Plantae
05/27/94	ERS 1995 (Fluor Database)		Cs-137			-0.031	pCi/g	BC Controlled Area	Vegetation	Plantae
05/27/94	ERS 1995 (Fluor Database)		Pu-239/40			0.0006	pCi/g	BC Controlled Area	Vegetation	Plantae
05/27/94	ERS 1995 (Fluor Database)		Sr-90			0.73	pCi/g	BC Controlled Area	Plant	Plantae
05/18/95	ERS 1996 (Fluor Database)		Co-60			0.081	pCi/g	BC Controlled Area	Vegetation	Plantae
05/18/95	ERS 1996 (Fluor Database)		Cs-137			0.06	pCi/g	BC Controlled Area	Plant	Plantae
05/18/95	ERS 1996 (Fluor Database)		Pu-239/40			0.00046	pCi/g	BC Controlled Area	Plant	Plantae
05/18/95	ERS 1996 (Fluor Database)		Sr-90			0.18	pCi/g	BC Controlled Area	Vegetation	Plantae

Table C-1. Information on Biota Samples in the BC Area. (14 pages)

Year	Reference*	Sample Description	Constituent	Field Instrument Levels	Less Than	Result	Result Units	General Site Name	Vernacular Name	Scientific Name
05/19/97	ERS 1998 (Fluor Database)		Co-60			0.0065	pCi/g	BC Controlled Area	Vegetation	Plantae
05/19/97	ERS 1998 (Fluor Database)		Cs-137			-0.04	pCi/g	BC Controlled Area	Plant	Plantae
05/19/97	ERS 1998 (Fluor Database)		Pu-239/40			0.0046	pCi/g	BC Controlled Area	Plant	Plantae
05/19/97	ERS 1998 (Fluor Database)		Sr-90			0.11	pCi/g	BC Controlled Area	Plant	Plantae
05/25/99	ERS-1999 (Fluor Database)		Co-60			-0.0035	pCi/g	BC Controlled Area	Plant	Plantae
05/25/99	ERS-1999 (Fluor Database)		Cs-137			-0.0051	pCi/g	BC Controlled Area	Plant	Plantae
05/25/99	ERS-1999 (Fluor Database)		Pu-239/40			0.0056	pCi/g	BC Controlled Area	Plant	Plantae
05/25/99	ERS-1999 (Fluor Database)		Sr-90			0.28	pCi/g	BC Controlled Area	Plant	Plantae

*See the reference section for details.

cpm = counts per minute.
det = detectable.

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